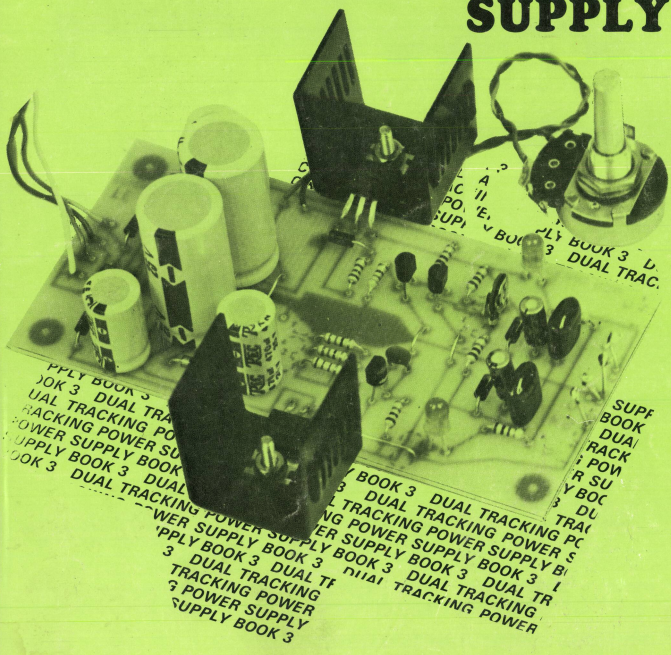
A
TALKING ELECTRONICS
PROJECT

BOOK 3

$3.95* NZ $5

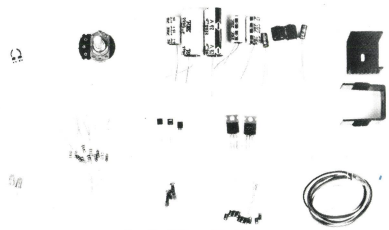
DUAL TRACKING POWER SUPPLY



POWER SUPPLY KITS

Complete kit of components as shown on Page 8:

We can supply most of the components for this project. The hardware and electrical items can be obtained at your local shop.

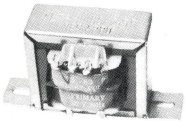


$13.45 P&P $1.50

ADDITIONAL KIT OF PARTS:
Knob for pot
SPDT switch
terminal block
cord clamp
3 binding post terminals
3 multi-strand leads
3 alligator clips

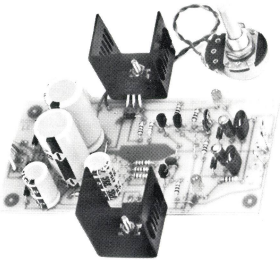
$7.80 Post $1.50

2155 Transformer $5.90
Post $1.50 each



6672 Transformer $7.50
Post $4.50 each

(use the lid for the heatsink)



LAYOUT OF THE PROJECT

We also stock the full range of kits and printed circuit boards for TALKING ELECTRONICS projects. See the current issue of TE for the list of kits and prices.

TALKING ELECTRONICS
35 Rosewarne Ave Cheltenham 3192 584 2386

DUAL TRACKING POWER SUPPLY

by

Colin Mitchell

and staff

A **TALKING ELECTRONICS** Project

A note from the author:

This project has been put together by Ken Stone with a little help from Colin Mitchell.

As with all our projects, they are experimental in their entirety.
We are not suggesting that this project is a precision supply with precise tracking capabilities. It is only intended as a low cost positive and negative supply which will be a handy piece of test equipment for powering a wide range of projects.
Its full value will be appreciated when working with operational amplifier circuits and other chips requiring positive and negative rails.

Most of these projects will be presented in forthcoming issues of TALKING ELECTRONICS and it is hoped that you will constuct this project and fit it into a neat case to compliment you work-bench.

First printing 1983
© Colin Mitchell

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You may photocopy up to 5 pages for school or club use but not class sets.

Bulk copies are available at half price.

*Recommended and maximum price only

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Introduction

This is the third book in the series. It features a power supply suitable for all types of applications and will be a valuable addition to your workshop.

Each project in this series has been introduced in a pre-determined order. It arrives just when you need it.

And this applies to the power supply.

We are presenting more and more projects in our main publication TALKING ELECTRONICS and this will be putting a heavy load on the power supply situation. Especially if you are buying batteries. Dry cells or ni-cads are fine if you require complete portability but if the project is bench mounted and operated for long periods, it will be costing you a fortune in batteries.

If this is the case, you will be very pleased with our curent project. It not only gives you a choice of output voltages from 0v to 30v, but also has a negative rail which can be adjusted from -8v to -12v. And this is ideally suited for powering op-amps or any chips requiring a positive and negative rail.

If you are not yet working with op-amps and the like, you will be soon. We are working towards including them in feature articles and you will be most impressed with their applications in small signal circuits; once you learn about how they operate. This will come in the near furure and so the power supply may not be fully utilized at this stage.

But don't worry.

The main intention of this project book is to teach through construction. The information you will gain through actual construction will outweigh 100 pages of reading. Nothing is more rewarding than producing your own projects, especially test equipment. And this is the area we have concentrated upon. This series of books revolves around test equipment which can be constructed for a fraction the cost of rival designs. To prove it we have put together a dual power supply for less than half the nearest rival. We have supplied all the circuitry and information for the electronics side of the project and left some of the mounting and cabinet work up to you.

Everyone will have different tastes in cabinet design. Some will like a wooden cabinet while others will bend up a fully aluminium design. To be quite honest, we could not find a suitable case at a reasonable price. This area of hardware is severely lacking in good designs and maybe someone someday will fill the gap. Until then I think a home-made case is equal to any available.

The second part of the book is a hand-written section on designing power supplies. It is not only a back-up feature but also a complimentary feature and will be an invaluable guide to producing a power supply to your own requirements.

It will also help you understand the operation of power supplies in general and promote a deeper regard for one of the hardest working sections of any large piece of equipment.

The presentation of these notes has been carefully designed to avoid any complex equations or physical quantities. Too often, the introduction of complex mathematical equations will send you running for text books and frustrates the situation more than instructs.

A simple form of instruction can leave a lot to be desired as it can leave out so many important facts. I hope this is not so with the notes. Once you read them and understand what is being presented, you can investigate more advanced text books.

Our main aim is to introduce and instruct at a beginning level. In this respect I think we have succeeded. The hand-written notes have already received a great deal of praise and comment. They are a very fast way to gain a factual understanding of a subject. They provide the key facts in a nutshell and you are quite at liberty to add your own comments to the sheets. These notes were originally presented in TALKING ELECTRONICS and have been compiled together to achieve continuity.

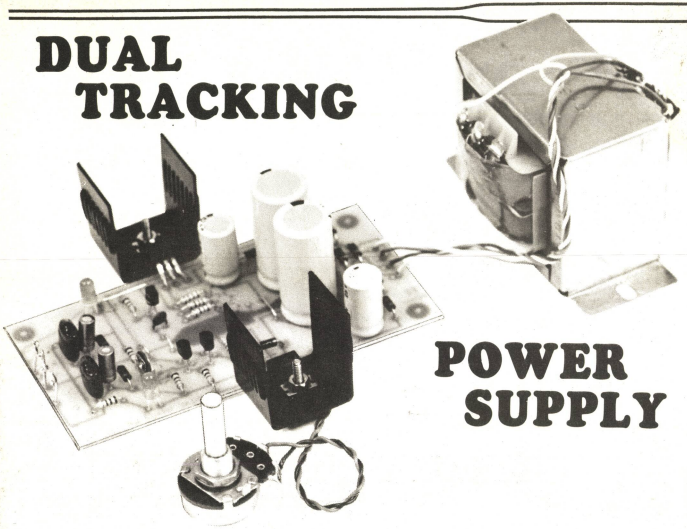
Before closing, let me add that I make mistakes just like everyone else. If you find a slip or mistake let me know. We will give you full credit for your astuteness, just like the two readers whose names appear in the power supply section. They found a couple of mistakes in the text and these have now been corrected.

I hope you find the notes beneficial and see your way to building the power supply project.

The best of luck with construction and don't short the outputs together. (you will see why in the text).

Colin Mitchell.
February 1983.

DUAL TRACKING POWER SUPPLY



A power supply is a very nice piece of equipment to have on the bench.

It produces a steady, reliable voltage with very low ripple and can take the place of myriads of dry cells or ni-cad batteries. It comes to its own when a heavy current is required for an extended period of time. In fact it has all the advantages of an accumulator supply without the hassles.

Power supply projects have been around for a long time but most of them had a number of short-comings. They were either too expensive to build or provided only some of the features required for modern experiments.

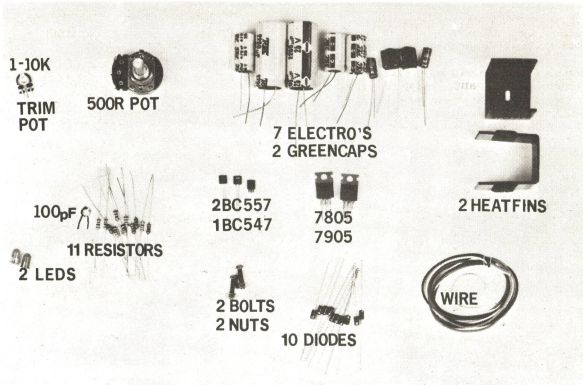
Our project fills the bill exactly. It provides all the necessary voltages for TTL and CMOS and incorporates the very important feature of having a positive and negative voltage of equal amplitude for op-amp investigation.

This has all been designed to fit on a simple PC board with only the minimum of wires to the front panel and power transformer.

One clever feature has been incorporated in the design to allow the positive voltage to reduce to reduce to zero when using a 5v regulator. This will be discussed in HOW THE CIRCUIT WORKS. The negative voltage does not track below -8v because the minimum operating voltage for most of the op-amps we will be discussing is ±9v and there is no advantage in the negative rail going below -9v.

The circuit has been specially designed to look simple and use readily available components. This makes the project very economical and possibly the only parts which will be new to you will be the 0 - 30v transformer and the 7905 regulator. The transformer can be duplicated in a number of ways but the 7905 is a negative 5v regulator and cannot be substituted with a positive type. In fact the lead-outs are different for positive and negative types so they cannot be inadvertently interchanged.

Let me not kid you. A dual supply has only very limited application. But when a split supply is needed, this one will be greatly appreciated. The most common need for a dual supply is when an op-amp circuit is being developed. They require a positive and negative rail in the



PARTS LIST

COMPONENTS FOR THE PC BOARD

1 - 220R ¼ watt
2 - 680R
2 - 1k
1 - 1k5
1 - 4k7
4 - 10k

1 - 5mm Red LED
1 - 5mm Green LED

1 - 100pf ceramic
2 - 100n ceramic
2 - 10mfd electrolytic 25v PC mount
3 - 470mfd electrolytic 25v PC mount
2 - 2200mfd electrolytic 25v PC mount

1 - 500R linear pot.
1 - 10k mini trim pot (can be 1k, 2k or 5k)

10 - 1N4002 diodes
1 - 7805 regulator
1 - 7905 regulator
1 - BC 547 transistor
2 - BC 557 transistors

2 - heat fins for regulators
2 - sets of nuts and bolts for heat fins
2 - sets of nuts and bolts for heat-sink
coloured hook up flex. 10 colours @ 20cm.
length of fine solder
small amount of thermal compound

ADDITIONAL PARTS

Transformer type 6672 or similar or 2 - 2155's
1 - knob for 500R pot
1 - SPDT power switch
1 - terminal strip for mains lead
3m - power cord (3-core)
1 - 3-pin plug (plug top)
1 - cord clamp
nuts and bolts as needed
3 - binding post terminals (1 red, 1 green 1 white)
3 - output leads (multistrand wire)
3 - coloured alligator clips to suit

HARDWARE ITEMS:

Parts for the cabinet include sheet aluminium, plyboard or particle board, nails, glue, screws, nuts, bolts rubber feet etc.

This will be a good fabrication exercise and don't forget to add holes or slots for the release of heat.

region ±*10 to* ±*15v.* Most op-amps will not work successfully on less than 9v and few can withstand voltages higher than ±18v.

To achieve a stable positive supply is quite an easy matter but a negative voltage is more difficult to obtain. You could use a set of batteries, another supply connected in reverse or build a miniature supply especially for the occassion. All this would tend to deter you from experimenting but now you don't have an excuse.

With this project you have the facility of producing both a positive and negative voltage and later in the TE programme we will be presenting projects with op-amp chips and other circuits requiring a split supply.
But don't let these forward applications deter you from building the supply now. It's construction is so economical that all its features will cost less than a normal single output arrangement.
We have used a very simple circuit and our first prototype operated first go without any need for modification.
The trim pot needed only a slight adjustment to equalize the output voltages and the supply was loaded to full current for a load test. Everything worked fine.

The main limitation with the supply is the power transformer. A 6672 is rated at 30v @ 1 amp and this means the output is equivalent to a 30v battery capable of supplying 1 amp for an extended period of time.
We found this transformer had a slightly lower rating but was adequate for the job. It has been chosen because it is cheap and can be used in three different modes to create 3 different output arrangements.
These are the three modes:

1. The 15v - 0 - 15v mode. This produces 0 - 15v output and -8v to -15v output.
2. The 0 - 30v mode. This produces 5v to 30v output. No negative output is available.
3. The 30v - 25v - 0v mode. This produces 0 - 22v output. No negative output is available.

15v - 0 - 15v MODE:

This arrangement provides dual output capability as described in the main section of this book. The PC board has been designed for this situation and the overlay allows for the connection of the 0v, 15v, 20v and 30v leads of the 6672 transformer.

Project cost will range from:
$40 - $60
depending on the type of cabinet used. Or as low as:
$25
if only the basic kit is built.

THE RATINGS

Positive supply:
0 to 15v at 1 amp.

Negative supply:
8 to 15v at 1 amp.

But:

When the positive supply is delivering 15v at 1 amp, the negative supply should only be delivering about 500mA. This is the limitation of the 6672 transformer. Other output arrangements are possible and are covered fully in the notes.

0 - 30v MODE:

Using the 0v and 30v leads will produce a power supply capable of delivering 5 to 30v. The current rating will be:
5v to 15v (approx) - 500 milliamps
20v(approx) to 30v - 1 amp.

The reason for the low current rating at the 5v end of the range is due to the 25v drop across the regulator. This will produce a power loss of 25 watts if one amp is required and this is in excess of the capability of the regulator. It will tend to shut down or fold-back when anything greater than 20 watts is being dissipated.

Note: This arangement is not suggested if 5v @ 1 amp is required.

30v - 25v - 0v MODE:

This will produce a 0v to 22v output and the current ratings will be similar to the above mode. The advantage of this arrangement is the very low voltage available for circuits using 1 or 2 cells in their supply.

HOW THE CIRCUIT WORKS

This is a brief analysis of the operation of the circuit. For a more detailed account, see the last few pages of the power supply notes in the back of the book.

The power transformer can be considered to be a single 30v winding feeding a bridge rectifier with the centre-tap becoming the neutral line. The cathode of the bridge diodes becomes the positive rail and the anodes become the negative rail. See diagram P 13.

The resulting voltage is smoothed by the 2200mfd electrolytic and this produces a DC voltage having a ripple less than 2v P-P.

From now we will discuss the positive section of the power supply and move to the negative section as the signal path takes us.
The DC voltage is fed to the 7805 through the IN terminal and it appears at the OUT terminal at a voltage which is 5v higher than the GND terminal. You will notice tha the GND terminal is not connected to the neutral rail but has a 500 ohm pot in the line. This is to enable the output voltage to be adjusted. The 220R resistor and 500 ohm pot form a voltage divider which "jacks" up the voltage to create the variable output.

These two resistors form a voltage dividing network and the voltage developed across the 500R pot is obtained via the 8 milliamps flowing in the GND line plus the current flowing from the 220R resistor. The actual voltage across the 500R pot can be obtained from a complex equation but for our discussion we merely say the pot increases and decreases the output voltage.

The output from the 7805 flows to a voltage dividing network made up of two 10k resistors and a 10k mini trim pot. One end of the divider is a positive voltage and the other end a negative voltage, having an equal amplitude. This means the centre point of the divider will be at a virtual earth or zero level. The 10k mini trim pot is included to make allowances for the slight difference in resistance of the two 10k resistors as they must be matched very closely for the positive rail to equal the negative rail.

The starting point for the biasing arrangement lies in the zeroing of the voltage on the voltage divider. This will mean the base of Q1 will be at a virtual zero level and the emitter will be about .55v higher due to the natural base-emitter voltage for a transistor which is only just beginning to be turned on. This voltage is transferred across to Q2 and causes it to be slightly turned on also.

The effect of the collector-emitter current flow in Q2 causes a voltage drop to be produced in the 10k resistor between the base and emitter leads of Q3. This voltage turns on Q3 and increases the voltage in the parallel combination of the two 680R resistors.
The -5v from the 7905 is increased by an amount determined by the 'turn-on' of Q3 and creates a voltage which is exactly the same amplitude as the positive voltage (or maybe a few millivolts less).

THE 0v FEATURE:

The positive voltage is capable of being reduced to zero and this has been achieved in a very interesting way.
Just as the voltage of a fixed regulator can be increased by jacking up the voltage on the GND terminal, the output can be reduced to zero by making the GND terminal go negative.

All the regulator "sees" is the voltage on the ground (GND) terminal. It then keep the output voltage 5v above this value if it is a 5v regulator. If the GND terminal is -3v, the output of the regulator will be 2v positive. If the GND terminal is -5v, the output will be zero.

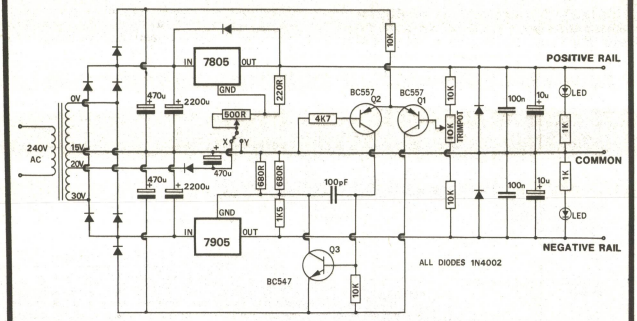
By using a tapping on the transformer which is 5v in the negative direction, we can add a simple rectifier and electrolytic to achieve a negative voltage. This is then fed to the GND terminal via a variable control to achieve a fully adjustable output.

SHORT-CIRCUIT PROTECTION

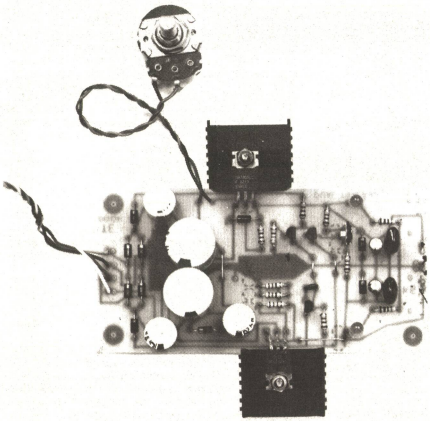
Two features have been included in the power supply to prevent the circuit being damaged by accidental short circuits.
The most important of these is the two diodes in the output. If the positive output is connected to the negative output, the regulators would be in a worse position than if they were shorted to earth. The internal circuitry in each regulator is diode isolated and if the output goes negative, the reverse biased diode becomes forward biased and the circuitry is destroyed.
To prevent this from happening we have added two diodes in the output. On short circuit, the top diode shorts the negative voltage to earth and the lower diode shorts the positive voltage to earth. And the regulators are saved.

The other safety feature is the diode connected across the 7805. This diode protects the regulator against shorts in the 2200mfd electrolytic from damaging the regulator. If the input voltage suddenly ceases, the output voltage will attempt to pass through the regulator in the reverse direction. The diode will reduce this to about .6v.

THE CIRCUIT



DUAL TRACKING POWER SUPPLY CIRCUIT



COMPLETED LAYOUT OF THE POWER SUPPLY

Note the relative position of each of the components corresponds to the circuit diagram.

The notes in this project book will mainly deal with the assembly of the PC board, wiring the transformer and heatsinking the positive regulator.

The PC board shown in the photo is our prototype on fibre-glass. The production run is paper bakelite and has an overlay showing the position of each of the components.

THE TRANSFORMER

A SHORT DISCUSSION ON THE TRANSFORMER AND HOW IT WORKS.

A power transformer is a brilliant piece of deception. It is much more complex than it appears. Nearly everyone takes a transformer for granted. They say "It works, so why worry."

But when you are designing a power supply, the transformer all of a sudden becomes a very important part of the design. Quite often the transformer becomes the limiting factor in the design and it may not perform as you had expected.
So it can be worthwhile to understand a few of its characteristics.

Take for instance, these three features:

Why is the core of a transformer laminated?
Why does an unloaded transformer take so little power?
How does the primary consume power according to the load on the secondary?

These are the points we will briefly discuss.

The whole secret of the operation of a transformer is the fact that it operates on alternating current. The AC mains.
So you cannot apply DC theory to its operation.
The fact that the primary has a DC resistance of 50 ohms does not come into any of our calculations at this stage.

A transformer is basically 2 windings which are connected magnetically.
We will firstly deal with the primary winding.
When a transformer is connected to the mains, the core is initially devoid of any flux or any magnetism. If we assume the voltage of the AC is passing through the zero point on the graph, we can explain what happens as the voltage rises.

Each turn of the primary begins to have current flowing through it and produces magnetic flux in the core. This flux crosses each other turn and this induces a voltage in each turn which is in the opposite direction to the supplied voltage. At the same time the other turns produce a magnetic flux which cuts our first turn to produce a voltage in the reverse direction.
This all occurs at the same time and thus the mains voltage finds that the reverse voltage is neary as high as the incoming voltage. Take this example: If the mains impresses a voltage of 600millivolts on each turn, the revese voltage being generated by the flux will be about 585 millivolts. Thus only 15 millivolts is available for each turn to produce the flux. This voltage is impressed across a resistance of about 1/20 ohm (for each turn) and will produce a current flow which is the quiescent current for the transformer. This is just sufficient to produce the maximum flux lines in the core material.
It should be noted that the flux is also producing a voltage in the secondary winding but since this winding is not connected to a load, no current flows.

If a load is connected to the secondary, a current flows. This also causes a higher current to flow in the primary.

The reason for this can be explained as follows:

The secondary supplies current to the load becauses of the voltage it generates. The current flow is determined by the value of the resistance of the load. This current and voltage is a direct

THE 6672 TRANSFORMER

result of the flux passing through each secondary turn. The current thus supplied, decreases the flux density in the core of the transformer and the primary receives slightly less back-voltage per turn due to the lower flux.

The result is a higher millivolt forward voltage and a higher current flows in the primary.

This effect can be increased to the limitations of the transformer. If the current increases excessively, a point is reached where there is insufficient flux to maintain a constant output voltage.
The output voltage will "drop off" and regulation will be lost.
Regulation is the ability to maintain an acceptable output at the required load current.

Now we come to the question:
"Why is the core of the transformer laminated?"
The core has one basic function. To concentrate the magnetic lines of force so that they pass through the windings of the transformer. These lines are commonly called FLUX.

The core provides a magnetic path for these. They pass down the middle of the core and around each side of the windings.By making the core out of thin sheets of metal we can produce a product in which the flux will perfer to travel in the longitudinal direction. In addition, the outside layers of the laminations are treated with an insulating material to make electrical conduction between sheets very difficult.

The reason for this is very interesting. Flux cannot differentiate between the core material and the copper of the windings.Whenever it passes through a metal it produces a voltage and according to the resistance of the material, a current will flow.

Take the core for instance. If the outside legs of the transformer were solid, the flux would pass through the outside leg and the material at the very edge of the leg, called the SKIN, would act as one large, thick, turn of wire. In fact it would act as one completely closed turn which we call a shorted turn and thus a heavy current would flow around the skin of the leg. The core material would get very hot and the transformer would cook.

By splitting the leg into lots of thin sheets, the outside path (or shorted turn) is now converted to the outside skin of each sheet but this time the generated voltage is much smaller, being only a fraction of the original due to the small amount of flux in the thin sheet. Thus the losses are reduced considerably by laminating the core.

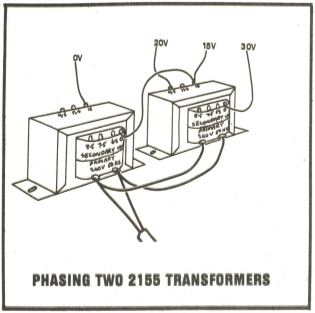
USING 2 2155 TRANSFORMERS

Two 2155 transformers can be used in place of the 6672 transformer with equal (if not better) performance.

A number of factors influence the ability of a transformer to supply the necessary voltage at full current.
In simple terms, this feature is called regulation and usually improves with the size of a transformer. Small transformers usually have poor regulation and for this reason it is best to use a single large transformer in place of two or three smaller units.

A single transformer is both lighter and cheaper than its equivalent in smaller units.

Thus the statement that two 2155 transformers will work as well as one 6672 is debatable.



PHASING TWO 2155 TRANSFORMERS

Two 2155's have some advantages and some disadvantages. Here they are:

ADVANTAGES:

1. Two 2155's are smaller and easier to mount.

2. They will distribute the load in the cabinet into two areas.

3. They will provide more area for cooling and ventilation.

4. 2155's are readily available.

DISADVANTAGES:

1. Two 2155's will cost more than one 6672.

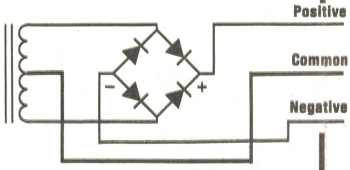
2. Two 2155's will need additional wiring and phase determination.

PHASING THE 2155's.

Two 2155's will need to be phased so that the output voltage is presented to the PC board as a single 30 volt winding. If the phase is correct, the voltage between the 0v tap on one transformer and the 15v tap on the other will be 30v. If the phase is incorrect, the output voltage will be zero across these terminals.

To produce the correct phasing, the 240v inputs on each transformer are connected in parallel as shown in the accompanying diagram and the secondary terminals are connected in series. We are assuming that both transformers have been manufactured with their primaries wound in the same direction and also the secondaries.

Whether you are using one transformer or two, the circuit can be simplified to a single centre-tapped secondary feeding into a bridge...as shown in the diagram.



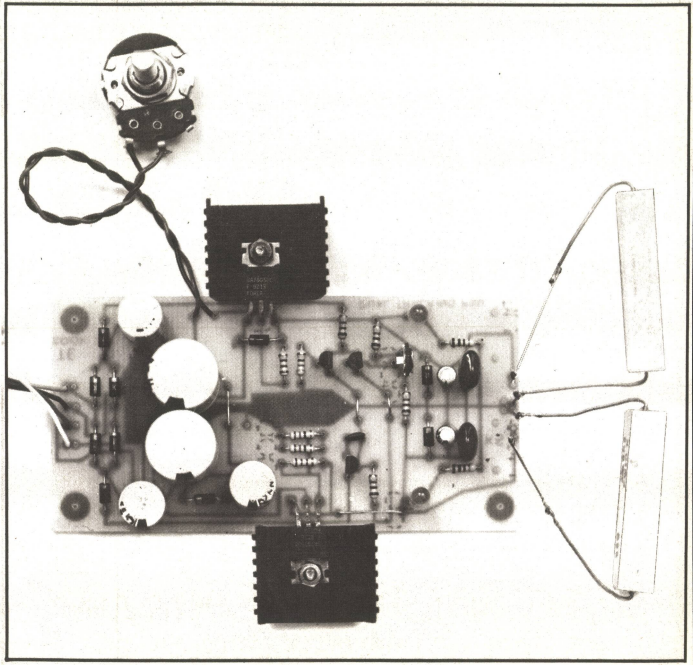
OUR FRONT-END

CONSTRUCTION

Before warming up the soldering iron you must get all the components organized. If you buy a kit, all the parts will be pre-selected. They will be the right size and shape to fit the board. If you intend to purchase the components from different sources and use some of the parts from your stock, you may fall into a number of traps. The most common of these is non uniformity of components. To me, neatness is very important. All the resistors should be the same size and all the electrolytics single ended types (PC types) and the mini trim pot should be small enough to fit directly into the holes.

Make sure the leads of the components fit into the holes on the board before starting to solder. This applies to the diodes, mini trim pot, regulator and large electrolytics. The resistors are all ¼watt. None of them will get hot when the power supply is in operation so tiny resistors are quite suitable.

Gather all the components and lay them out so that they are in a position exactly relative to the final placement on the board. This is very important because when you are soldering,



you cannot concentrate on selecting the correct component and make a good connection at the same time.

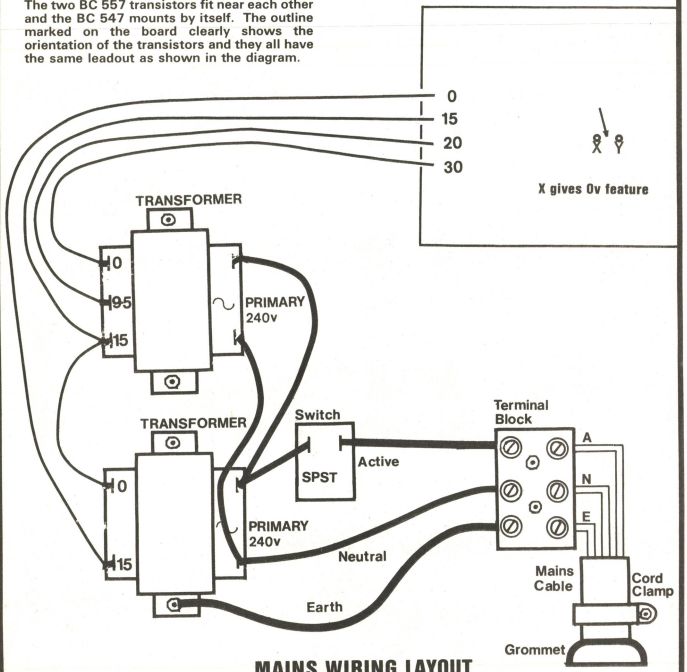
Make sure you understand which end of the diode is the cathode before starting. This also applies to the electrolytics. We have identified the positive on the layout but the negative is usually identified on the body of the component. The metal side of the regulator faces towards the edge of the board so that it can be bolted onto a heatsink via a nut and bolt and a little thermal heat compound.

The two BC 557 transistors fit near each other and the BC 547 mounts by itself. The outline marked on the board clearly shows the orientation of the transistors and they all have the same leadout as shown in the diagram.

The two light emitting diodes must be inserted as shown as they are a polarised component and will not work in the reverse direction.

Now we are ready for assembly. Use fine or very fine solder for the joints and tin the soldering iron ready for the start.

How you start or where you start is not critical but the most important point is to make a very neat job.



MAINS WIRING LAYOUT

SELECTING X or Y

The board contains 3 jumper wires and these are clearly shown on the overlay. On top of this, in the centre of the board, is a selection link. It is actually a jumper which enables you to select the 0v to 15v mode using the X hole or 5v to 15v using the Y hole. We suggest using the X hole to give the fully variable output. This makes a total of 4 jumper links.

Next add the 10 diodes. The white band painted around one end is the cathode and it goes upwards or to the left on the board. Push the leads through the holes so that the diode touches the board. This will improve the heatsinking through the copper tracks on the board. Bend the leads slightly apart so that the diode stays in position, ready for soldering. Solder the leads and cut the surplus flush with the board. Continue with the rest of the diodes.
Eleven resistors are needed for the circuit. They are fitted one at a time, soldered and the leads trimmed flush.

The mini trim pot can be any value from 1k to 10k and the best type to buy has thin leads which will fit down the 1mm holes.

The 100pf cap is the next part to be soldered to the board.

The two light emitting diodes are fitted so that the cathode lead (the short lead) fits down the hole identified with a line.

The two 10mfd electrolytics and 100n capacitors are the next components to be fitted to the board.

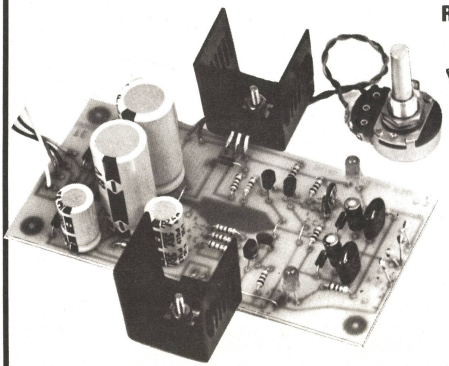
The 7805 and 7905 are soldered in position with the metal face near the edge of the board.

The two 2200mfd electrolytics are now added to the board, make sure the positive lead goes down the correct hole. Remember that the negative lead is identified on the body of the electrolytic.

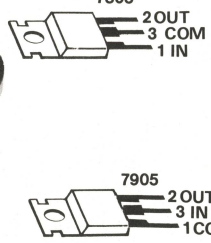
The three 470mfd electrolytics are the last components to be added to the board.

Cut short lengths of coloured hook-up wire for the 4 input leads, 2 leads for the 500R pot and 3 leads for the output lines. These should be long enough to allow the board to be taken out of the case for servicing, if needed.

The remainder of the construction will vary from constructor to constructor and the easiest way to present the wiring is via a diagram. We have shown the layout for a pair of 2155's as the 6672 transformer will be a direct connection.



REGULATOR PIN-OUTS



5v 1.5 AMP

For the special requirement of 5v at 1.5 amps, this power supply project requires a small modification.

You must firstly be aware that the dual voltage facility will not be available nor will the variable voltage be easily obtainable. We are catering for the situation where exactly 5v is required for a TTL project or other similar needs.

The 1.5 amp current situation is only recommended for short periods of time as the 6672 transformer is only designed for 1 amp loading.

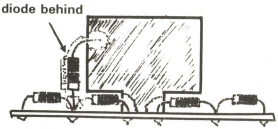
To enable the bridge rectifiers to handle 1.5 amps, it will be necessary to parallel up two of the diodes to cater for the higher current.

You can use two extra diodes out of your parts-box or remove the two outside diodes from the board as they will not be needed. There are the diodes which supply the voltage to the transistor stages.

Refer to the diagram for the position of the two diodes which must be paralleled up. The two added diodes can be soldered to the copper side of the board or the top side as shown in the diagram. Either way you will need to take advantage of the heatsink and the leads must be keps as short as possible so that the heat can be effectively dissipated.

Keeping the diodes cool is most important when the maximum current is required.

The main electrolytic can also be increased to give added smooting but this not as important as attending to the diodes.
Remember the regulator must be allowed to have at least 3v across it to maintain regulation. The regulator must also be perfectly heatsinked with thermal grease and mounted on a large heatsink to capable of supplying the necessary wattage.



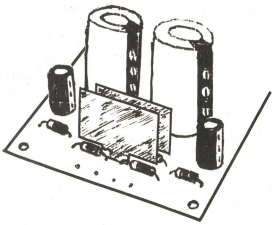
HEATSINKING THE DIODES

For any current requirements above 1 amp, you will find the power diodes will be fairly warm to touch after a few minutes of operation.
This is because they will be dissipating nearly 1 watt of power per diode because the voltage drop across the junction rises to nearly .9v as the current rises to about 1 amp.

If you intend to operate the power supply for long periods of time at a farily high current level, the diodes must be heatsinked. This will not only lengthen their life but also prevent the possibility of one or more of them becoming damaged.

The best heatsink is a small piece of sheet-metal cut from the lid of a can. This is soldered directly to the leads of two diodes as shown in the diagram. You will see that this is not creating a short circuit as the copper track under the board also joins these two diodes.

Another piece of sheet-metal can be used to heatsink the other two diodes and these can be stood upright and parallel to each other. To prevent them from shorting against each other, a small piece of insulating tape can be stuck on the inside of each fin. The diodes will love you for the attention they receive and if your are quick at soldering, you will not damage them.



HEATSINKING THE REGULATORS

The photos of this project show heat fins on the two regulators. These heat fins are only intended as run-up components, to test the supply and get it operating. Each fin will only dissipate 5 to 6 watts and this well below the expected dissipation when the supply is delivering 1 amp.

To act as a suitable heat sink, I looked around for something everyone would have in their parts box. I found it in the form of a lid from a jiffy box which is the same size as the PC board for this project. This enables it to match perfectly with the holes in the PC board.

Only the positive regulator needs an additional radiating fin as the current required from the negative line will be small and the mini heat fin will be capable of dissipating any heat generated by the 7905.

To enable the sheet of aluminium to attach to the PC board, it is necessary to make a cut 1 cm from each end and cut into the sheet 1 cm to make a tab containing the corner hole. This tab is bent to 90° and the same is done with the hole in the other end. The strip of aluminium between the two tabs is bent to 90° in the opposite direction. See the sketch.

Sit the aluminium sheet on the PC board and make sure the holes align. Next mark the aluminium with a scriber through the mounting hole of the regulator and drill this hole in the sheet to take a short 4BA nut and bolt.

After the hole has been drilled, use a flat file to remove the filings and prepare the face of the aluminium near the hole to meet the surface of the regulator. Do this on a flat surface and repeat on the other side. The mini heat fin will be used in conjunction with the aluminium sheet to prevent a hot spot from developing near the regulator. The aluminium sheet itself is not thick enough to transfer the heat quickly from the face of the regulator and an additional thickness is required. Thus the need for the heat fin.

Prepare the surface of the heat fin with the flat file and sit it onto the aluminium sheet to observe their flatness. You should not be able to see any light through the crack . . the closer the fit the better.

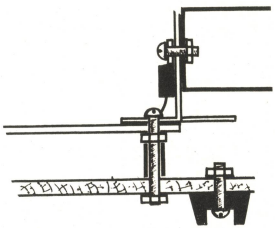
Attach the aluminium sheet to the PC board with two nuts and bolts. Smear a very small amount of thermal compound on the four conducting faces. Clamp the regulator and mini heat fin to the aluminium and screw them up tight so that the thermal compound squeezes out of the cracks.

You have now produced the cheapest and best heat fin for 10 watts dissipation. It will probably dissipate more heat but 10 watts is about the maximum we are producing.

It is an interesting exercise to load up the power supply and feel the heat fin after 10 or 20 minutes of operation. With 10 watts of heat being generated the fin is quite hot but still able to be touched. You can sense the temperature the regulator the temperature is so high that you might wonder how the regulator can still be operating.

Without the mini heat fin you run the risk of the regulator overheating and shutting down. So it forms a very important part of the cooling.

We have only added a large heat fin to the positive line as the negative rail will be supplying only a very small current under normal operation. If you find the heat fin on the negative rail gets too hot, you can add an additional radiator at a later date. Anything up to 150 milliamps on the negative line can be delivered without overheating the regulator.

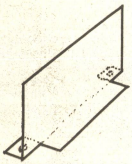


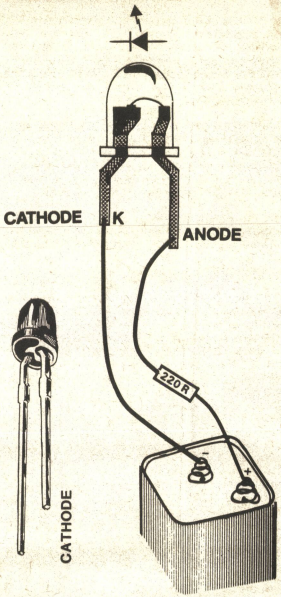
One possible arrangment for the regulator heatsink and mini fin is shown in the diagram.
The PC board is attached to the wooden base via a long screw and sleeve. This screw also holds the heatsink in position. Note the heatsink is bent to 90° at its base to produce a foot which can be clamped to the board.

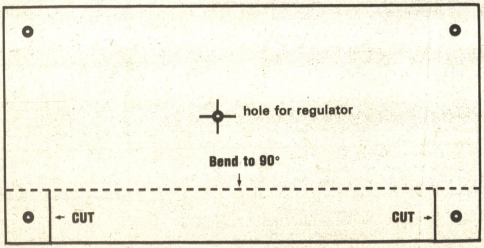
IDENTIFYING THE LEDs.

The two light emitting diodes are mounted on the board in opposite directions. There is no intentional reason for this, just circuit layout. If you are using new LEDs, one lead will be longer than the other. The short lead is the cathode. Otherwise, if the leads are the same length, you will have to use one of two other methods for determining the cathode. Mind you, they won't be damaged if you insert them into the board around the wrong way. It's just nice to get things right the first time.

When soldering the LEDs to the board, do it quickly and keep the leads long. LEDs can be very easily destroyed by heat. But before soldering them, look into the body of the LED. You will se one lead is larger than the other. This is the cathode. The fine piece of wire joining the two leads is not a filament, it connects the leads to the light emitting crystal. The other methode of determining the cathode is to look for a flat on the side of the LED. It indicates the cathode.







SUBSTITUTES

The components in this project are really not as critical as you think. You will be pleasantly surprised when I tell you the range of values you can use.
I will start at one end of the board and work across.

The diodes can be any voltage from 100v to 1000 volts. Only the current rating is important. They must be capable of handling at least 1 amp. The 4 diodes in the bridge are the critical ones. They will be required to pass the current when the supply is operating. The other diodes pass a smaller current or are only used for short periods of time.

The two 470mfd electrolytics which smooth the supply for the transistors are mounted near the set of bridge diodes. They can be 100mfd, 220mfd or 330mfd, without affecting the performance.
The 470mfd producing the negative voltage cannot be reduced in value without affecting the negative supply to the regulator.

The 2200mfd main reservoir capacitor can be reduced to 1000mfd if the higher value is not available. If only one 2200mfd is available, it should be used for the positive section.

The 7805 can be replaced with a 7806 or 7808 or even a 7812, however it may not be possible to reduce the voltage to zero with the 12v type.

The 7905 can be substituted with a 7906 or 7908 and the same conditions apply. It will not be possible to get lower than 2v more than its rating.

The 220R resistor can be substituted with a 180R 270R or 330R.
The 4k7 can have any value from 2k2 to 47k.
The two 680R resistors can be changed to 560R or 820R.
The 1k5 can be 1k2 or 1k8.
Any of the 10k resistors can be changed to 8k2, 12k or 15k. The only important point is the two resistors in the voltage divider network must be the same value so that the mini trim pot has a chance of trimming their value exactly. The mini trim pot can be any value between 1k and 10k, however the higher value will make adjustment more sensitive.

The two 1k current limiting resistors for the light emitting diodes can be 820R, 1k2 or 1k5.

The 10mfd electrolytic in the output can be 4.7mfd or 22mfd without any effect on the performance.

It boils down to any of the components can be changed to a value higher or lower than the suggested value and the only components which are critical are the two resistors in the voltage divider network.

IDENTIFYING THE TRANSISTORS

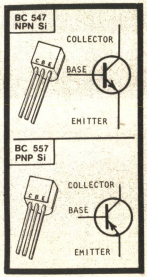
Both PNP and NPN transitors are used in the tracking circuit.

They both look exactly the same and have the same pin connections.
But you cannot swap them over or used them around the wrong way and expect the circuit to work. Because it won't.
Use only NEW transistors as they are so cheap to buy that it is not worth spoiling the project for a few cents. We use BC 547's and BC 557's for nearly all our projects and it will be worth while stocking up on a quantity of them if there is a saving for bulk lots.

HOW TO TEST UNMARKED TRANSISTORS.

If the numbers have rubbed off your transistors, they can be identified by using the transistor tester on the LOGIC DESIGNER or you can use a multimeter and the instructions on DATA SHEET 2.

When clipping to the leads, rmember that they are normally bent to form a tripod and this identifies the collector, base and emitter. If the leads are in-line, you will need to go by the flat on the transistor to pick out the collector. The holes in the board form a triangle and the outline of the body is also shown, so the transistor can only be inserted one-way-round.



THE MAINS

It cannot be too strongly stressed. This is a mains operated project and a great deal of caution is required when connecting any type of project to the mains. It is so easy to make a mistake in the wiring of something simple. Something like wiring a plug top, switch or socket. If this happens on the mains side of things, the result could be lethal.

And we always tend to make the greatest number of mistakes when something looks easy.

It's a simple truth. The easier the job, the more chance of making a mistake. This is because we electronics experts are complex human beings and when we are required to handle a simple operation, we let out guard down. And what happens. We do it wrong.

Whenever I do something simple I get it checked. And quite often I have made the simplest of mistakes.

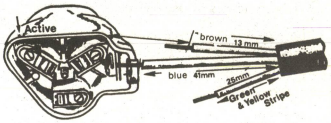
So the lesson is there.

This project requires checking.

It is absolutely essential to get the finished project checked by someone else. Anyone else. As long as it is not yourself doing the checking. You cannot proof your own work.

The plug and lead should be firmly connected via the wiring and the outside cover of the plug-top attached to the base. This is only simple intelligence but it is amazing how often the cover is left loose. The outside cover of the flex should enter the plug-top as far as possible so that no wires are visible.

WIRING A PIGGY-BACK PLUG



It is best to use a piggy-back plug so you can still use the mains outlet for your soldering iron or other lead.

A good cord anchorage will be needed where the cord enters the cabinet so that the lead does not pull on any of the wiring inside the case. The hole for the flex should also be large enough so that the lead does not rub against the metal hole in the case.

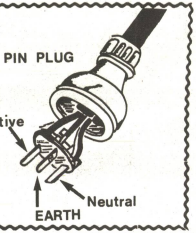
Preferably the cord anchorage should be mounted inside so that the hole is prevented from chaffing the cord.

Provide plenty of flex for the project because you never know where it will be used. A long lead is always appreciated.

WIRING A PLUG-TOP

This simple operation looks fool-proof but needs concentration to avoid a mistake, because the new colour-code for the flex is so confusing.

Begin with the GREEN or YELLOW striped lead to the EARTH or plated pin. The RED or BROWN goes to the left-hand ACTIVE pin and the BLUE or BLACK to the right-hand or NEUTRAL pin.



Ideally an electrical engineer or technician should look over the mains side of the wiring to see if everything is tight, neat and well-insulated. But if this is not available, a teacher, parent, adult friend will be willing to follow the layout and tug at the flex and wiring.

Every part of the mains wiring should be insulated to the touch and no exposed wires should be visible. Only a screwdriver should be able to undo the screws on the terminal block.

RUNNING-UP THE POWER SUPPLY

This secion deals with loading the power supply to rated current to check all components.

When all the parts have been mounted on the board, the next stage is to load the output so that about 1 amp is drawn from both the positive and negative rails. This lets you know the power supply is operating and will supply a current. More than that we are not testing. We are only performing a run-up proceedure and the current will not be required for more than about 10 seconds.

The easiest way to load the supply is to connect two 10 watt resistors to the output. These can be either 8R2 or 10R and you will need a voltmeter to set the voltage fairly accurately.

Lay the project on the bench as shown in the photo and have a multimeter ready to make a very quick voltage adjustment.
Turn the supply ON and set the voltage to 8.2 volts for the 8R2 resistor or 10 volts for the 10 ohm resistor. By simple ohms law we have created a current flow of 1 amp in the output.

We are now going to make a very approximate statement. The power loss in the load is equal to the loss in each of the regulators. This is due to approximately half the voltage dropping across the regulators and half across the load. This means they will heat up to about the same temperature given the inference that the volume of the load is about the same as the regulator and heat fin.

In any case the run-up procedure calls for the supply to be turned on for 10 seconds and then switched OFF. Feel the temperature of each load resistor. They should feel about the same. Feel the two heat fins. They should also be about the same temperature.

This is only a simple test to test the outputs under load.
If you keep the power applied for more than 30 seconds you will burn your fingers on the load resistor, just as I did now. The heat fin will also get extremely hot and may exceed the normal limits of the regulator.

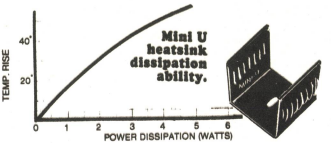
If any of the four heat-dissipators remains cold, you will need a multimeter to find out what is going wrong.
When you are testing the section containing the cold component(s), do not let the other section get too hot. Disconnect the load from the working stage and concentrate on the faulty section.

Firstly check the input voltage to the regulator, then the 'jacked-up' voltage on the GND connection. Finally measure the output voltage. If the input voltage is missing, it could be two faulty diodes, a dry joint or a break in the PC track. If the GND voltage is zero, the output will be only 5 volts and this could account for the cool resistor. If the GND terminal is jacked-up, and the output is zero, the regulator could be open.

If the regulator is getting very hot and the load is cold, it will be a short across the output, but not a short inside the regulator as it is a series-pass device and the shorting current must flow to earth. You can also refer to the notes dealing with a damaged power supply, later in the project.

Hopefully you will not meet any of these problems and the 4 heat-dissipating components will be nice and hot.

You are now ready for the next stage which is mounting the board and transformer in a case, cabinet, box or chassis.



CALIBRATING THE OUTPUT

The diagram opposite shows a suitable layout for the front panel. The scale for the output voltage is created with the aid of a multimeter set to a suitable voltage range.

Connect the voltmeter across the output terminals and turn the pot to read 5v on the multimeter. Mark the position on the scale.

Increase to 10v and again mark the position. The highest voltage will be about 15v and this is also marked on the dial.

You can include a panel meter to monitor the output voltage if you wish however the output voltage is generally not too critical and a scale around the pot is usually sufficient. You can use a multimeter to read the exact voltage as required.

COMPLETING THE POWER SUPPLY

Although we have said the layout of the case will be left up to you, I think a few pointers on good layout and design will be in order.

To pass a good design award, you will need to consider three aspects:

1, Perfect safety and insulation from the mains.
2. Good ventilation.
3. Good layout for the front panel.

First and foremost is the safety aspect.
If you are going to fabricate your own case, you have a choice of three materials: METAL, WOOD or PLASTIC. You can either use one material throughout or combine two or more together.
Sheet aluminium is the easiest metal to work with however wood is most versatile and the most pleasing when completed. Plastic will be the most difficult to work with and the most expensive to buy as sheet PVC or perspex is very expensive when bought in cut sizes.

You may like the idea of making wooden ends and bending up the base and front panel from a piece of sheet aluminium. The back and top can be made from another sheet. This will give a join at the top front edge and to avoid any joining problems you could make the base and back in one section and the front and top in another section. This will take the join to the back of the cabinet.
When using metal for the base and front, all the terminals, PC board and LEDs have to insulated from the metal. The use of wood throughout will eliminate this.

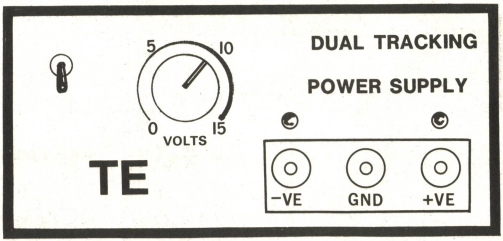
Any way you do it, it will come out cheaper than the over-priced cabinets on the market.

The most important design feature of a good cabinet is ventilation. The transformer and heatsink must have a draft of air passing through the base and out the top or near the top. Without this, the parts will gradually heat up and heat up until they finally cook. It may take a few hours but it will eventually occur and in the process you are exposing the case to the risk of fire.

Apart from an abundance of holes, you will need to have clearance between transformer and case of at least 1 cm and the top of the heatfin should be 1 cm from any case-work. The top of the heat-fin can be bent over to create this clearance if necessary. The PC board should be mounted on stand-offs so that the track-work does not short against the base.

Depending on your selection of one or two transformers, the internal layout should closely follow the layout diagram. It should be kept neat and tidy with the mains side of the project well away from the secondary voltages. No exposed leads should be visible and no connections to the mains available to the touch. Even a piece of electrical tape or a plastic sleeve is sufficient to prevent accidental contact. This is absolutely essential as some constructors say "I made it, so I can fiddle with it." and they become a little blase.

When laying out the front panel, centralise the controls and terminals to make them look appealing. Use the appropriate colour for each output and make sure it is adequately labelled. Don't forget, someone else may be using your supply one day and an unlabelled supply may lead to an accident.



A SUGGESTED FRONT PANEL LAYOUT

USING THE POWER SUPPLY

I shouldn't need to give you too many ideas about the uses for the power supply. By now you will be rearing to put it into action - even before it's complete.

I can only say it will be the next best investment after buying a set of nicad batteries. Not only will it last longer than rechargeable batteries but you won't have the worry of a project dying in the middle of development for want of a little juice.

The only thing I must say to you is: do not short the positive terminal to the negative terminal, "to see if the power supply is working." This is the most dangerous act of all for a dual supply and even beats shorting an output to earth.

When you short the positive to negative you are actually trying to make the output go below zero voltage and this will turn on an isolating diode inside the regulator. Without the two output protection diodes you would damage both regulators. But these diodes are not all that robust. With the high current and the added zap of an electrolytic, one of them could be damaged and go 'short'.
A tiny 10 ohm resistor connected on the outside of the supply to the negative terminal will prevent any likelihood of this happening and the low voltage drop across it, when drawing a few hundred milliamps, will be small.

Before connecting the output leads to any project or even a set of nicad cells, it is most important that the polarity of the leads be correct.

The output terminals should be colour coded with red for the positive output, green for the common line (or earth line) and white for the negative rail.

Use leads of a similar colour code and also matching alligator clips.

With the power supply switched off, connect the zero volt line (the common or earth line) and then the positive line. Switch the power supply ON.

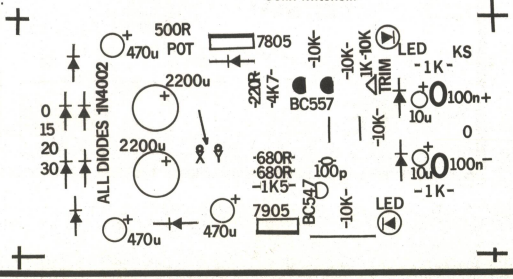
If you think a project you are powering may have a short circuit or consume too much power, the only protection device I have used with success is a small 10 ohm resistor of ¼ watt rating, in one of the lines. It doesn't matter which line contains the resistor, so long as it is well away from any other components as it may go up in smoke and catch fire.

If a short is present or occurs, the resistor will go up in smoke. If the project takes a heavy current, the resistor will go up in smoke quickly. The resitor may be wasted but it serves as a very handy indicator. It could save a number of expensive components from being damaged.

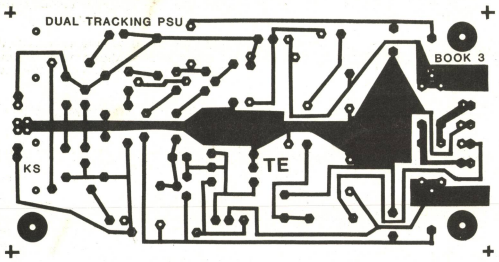
The only way of testing the power supply for the 1 amp current flow is via an 8R2 or 10 ohm wire wound resistor capable of dissipating 10 watts. An ammeter across the output will not indicate the correct current flow because it will create a short on the output and the regulator will shut down.
If you only have low wattage resistors to do the testing, a 10 ohm ¼ watt resistor can be flicked across the output while holding the body of the resistor in your fingers. About ½ second after touching the output terminals, the heat from the resistor will reach your fingers and you will know power is available!

All the best with the project and remember NO SHORTING!

Colin Mitchell.



Full size PC artwork:



The page behind the PC artwork is blank so that you can expose through the paper.

Send in your ideas . . .

Help us to create new and exciting projects.

Let us know how you liked this project and any special uses you have put the power supply to.

Our intention is only to get you started with a project and leave any further experimenting up to you. Some of the adaptions and modifications which have been sent in from the previous projects have been quite ingenious. Maybe you have some ideas for the power supply. The previous suggestions have already been put into operation and our presentation has benefited from them.

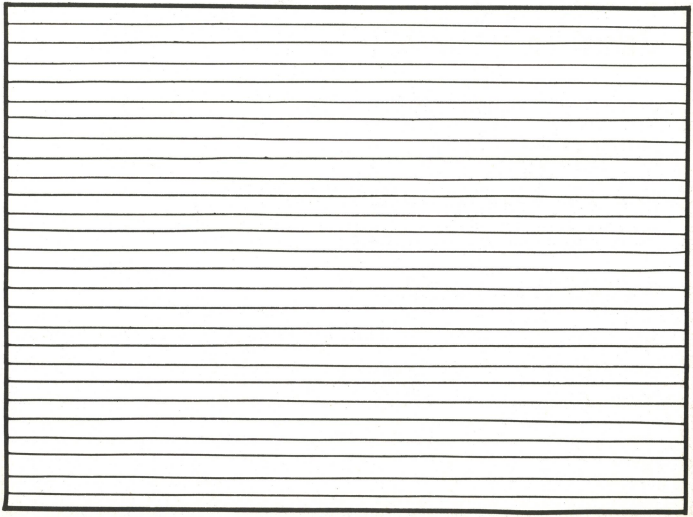
The next book in the series is a digital voltmeter using readily available chips to show each section operates. Watch for it soon.

Name:

Address:

Post to:

TALKING ELECTRONICS
35 Rosewarne Ave.,
Cheltenham, 3192.



A short course in

POWER SUPPLY DESIGN

By Colin Mitchell
B. Electronic Engineering

Understanding the use of a 3-terminal regulator

POWER SUPPLY DESIGN

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The elements of a modern power supply are simple:

- **A transformer**
- **Bridge rectifier**
- **High value electrolytic**
- **Regulator chip**

With these few elements we can build a very effective power supply capable of delivering high currents with very little ripple. This is especially important in TTL circuits where high rippple will produce all kinds of trouble.

Even though the number of components is few, a great deal of theory lies behind the construction and design of a power supply.

These notes concentrate on facts relevant to the dual tracking power supply in this issue but can be extended to a wide range of individual requirements.

It's very rewarding to learn some of this theory.

Here's how it all goes together:

A

THE DUAL-TRACKING POWER SUPPLY FEATURED IN THIS ISSUE WILL PROVE TO BE A VALUABLE INCLUSION IN THE WORKSHOP

AND IT MAY PROMOTE A LITTLE FURTHER INVESTIGATION INTO THE DESIGN OF A CIRCUIT TO SUIT A PARTICULAR REQUIREMENT.

BUT BEFORE YOU TACKLE ANYTHING ALONG THESE LINES IT WILL BE BENEFICIAL TO READ THROUGH THESE HAND-WRITTEN NOTES AS THEY ARE SURE TO MAKE YOUR TASK EASIER IN THE FINISH

A POWER SUPPLY CAN BE DESIGNED FOR ALMOST ANY REQUIREMENT. THE ONLY LIMITATION IS THE NEED FOR A POWER POINT. IN OTHER WORDS THE PROJECT CANNOT BE PORTABLE.

BUT IF A POWER SUPPLY CAN BE USED IT WILL SAVE THE COST OF BATTERIES AND AVOID THE FRUSTRATION OF A FLUCTUATING VOLTAGE OR A SUPPLY RUNNING OUT. BATTERIES ARE IDEAL FOR PORTABILITY BUT FOR CONTINUED OPERATION, A POWER SUPPLY IS THE ANSWER.

FEATURES OF A POWER SUPPLY:
- DELIVERS A CONSTANT VOLTAGE
- CAPABLE OF DELIVERING HIGH CURRENTS
- CAPABLE OF DELIVERING HIGH VOLTAGES
- CHEAP TO RUN
- ABLE TO CHARGE NI-CADS.

FIRST CONSIDERATIONS: DETERMINE IF THE DUAL TRACKING SUPPLY WILL SATISFY THE REQUIREMENTS. IF NOT DESIGN THESE NOTES WILL COVER ALL THE THEORY BEHIND A SIMPLE POWER SUPPLY AND PRESENT SOME GUIDELINES FOR EXTENDING THE RANGES

CURRENT RANGE: POWER SUPPLIES FALL INTO 3 CATEGORIES ACCORDING TO THEIR CURRENT CAPABILITIES.

1. LOW POWER — USUALLY 150mA 250mA OR 500mA.
2. MEDIUM POWER — USUALLY 1AMP TO 2AMP.
3. HIGH POWER — 3AMP 5AMP 10AMP AND HIGHER.

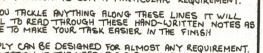
NOTE: THE VOLTAGE OF A POWER SUPPLY IS COMPLETELY INDEPENDENT OF CURRENT. AT ANY CURRENT FLOW, THE VOLTAGE RANGE CAN BE 1·5v — 1,000 VOLT.

THIS MEANS A POWER SUPPLY CAN BE DESIGNED FOR 3v @ 10AMPS OR 110v @ 150mA OR 32-0-32 @ 5 AMPS THE ONLY DIFFERENCE BETWEEN THESE WILL BE THE PHYSICAL SIZE OF THE SUPPLY, TRANSFORMING & COST.

REMEMBER: POWER SUPPLIES BE MAINS OPERATED PROJECTS AND SAFETY WITH THE MAINS IS ESSENTIAL.

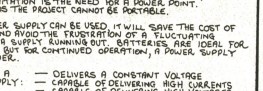
B

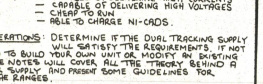
A POWER SUPPLY CONSISTS OF 3 SECTIONS



THESE NOTES WILL OUTLINE HOW THE 3 STAGES CAN BE COMBINED TO PROVIDE THE BEST AND CHEAPEST POWER SUPPLY FOR YOUR REQUIREMENTS

THE POWER TRANSFORMER





THESE ARE THE 4 MOST COMMON TYPES OF SECONDARY WINDINGS. THE PRIMARY WINDING DOES NOT CONCERN US AND IT WILL USUALLY BE LEFT OFF CIRCUIT DIAGRAMS. WE ONLY DEAL WITH THE SECONDARY WINDING

NOTES: THE PRIMARY AND SECONDARY WINDINGS ARE USUALLY MARKED ON A TRANSFORMER. YOU MUST KNOW WHICH IS WHICH
- THE TRANSFORMER WILL NOT WORK IF YOU CONNECT THE SECONDARY TO THE MAINS. IT WILL GET VERY HOT AND "COOK."
- THE SECONDARY PRODUCES 1v RC FOR EACH 3 = 8 TURNS OF WIRE
- WHERE THERE ARE 2 OR MORE WINDINGS IN THE SECONDARY, THE THICKER WIRE SUPPLIES THE HIGHER CURRENT.
- A TRANSFORMER DOES NOT GIVE "DIRECT CURRENT" IT SUPPLIES ONLY "ALTERNATING CURRENT" (AC)
- YOU DON'T NEED TO KNOW WHICH SECONDARY LEAD IS "IN PHASE" WITH THE MAINS
- YOU CANNOT MEASURE THE RESISTANCE OF A WINDING TO DETERMINE ITS CURRENT OR VOLTAGE RATING
- THE CIRCUIT SYMBOL FOR A TRANSFORMER DOES NOT INDICATE THE SIZE OF ANY WINDING OR THE CURRENT OR WATTAGE OR VOLTAGE.

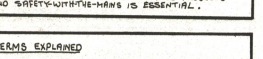
C

SOME OF THE TERMS EXPLAINED

RMS — THE MAINS VOLTAGE IS RC. (ALTERNATING CURRENT) AND ON A CRO (CATHODE-RAY OSCILLOSCOPE) IT WOULD APPEAR LIKE THIS!

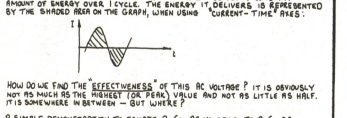
YOU CAN SEE THAT THE VOLTAGE IS RISING & FALLING AND IN 1 CYCLE WE HAVE A MINIMUM & MAXIMUM VALUE: BUT AC POWER IS NO USE IN ELECTRONICS. IT MUST BE RECTIFIED & THIS IS WHERE SOME NEW TERMS ARE INTRODUCED.

SINCE THE AC IS RISING & FALLING, IT DOES NOT SUPPLY A CONSTANT AMOUNT OF ENERGY OVER 1 CYCLE. THE ENERGY IT DELIVERS IS REPRESENTED BY THE SHADED AREA ON THE GRAPH, WHEN USING "CURRENT-TIME" AXES.



HOW DO WE FIND THE "EFFECTIVENESS" OF THIS AC VOLTAGE? IT IS OBVIOUSLY NOT AS MUCH AS THE HIGHEST (OR PEAK) VALUE AND NOT AS LITTLE AS HALF. IT IS SOMEWHERE IN BETWEEN — BUT WHERE?

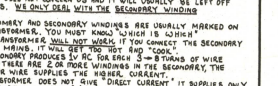
A SIMPLE DEMONSTRATION TO EQUATE A 6v AC VOLTAGE TO A 6v DC VOLTAGE IS VIA 2 LAMPS AS IN THIS EXPERIMENT.



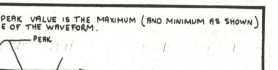
TO PRODUCE EQUAL BRIGHTNESS, THE AC VOLTAGE WAVE FORM WILL HAVE TO HAVE A MAXIMUM VALUE OF 8·4v. NOW TO FIND THE HEATING EFFECT OR LIGHTING EFFECT OF AN 8·4v RC VOLTAGE, WE PERFORM A MATHEMATICAL OPERATION CALLED RMS. RMS MEANS FINDING THE ROOT OF THE MEAN (AVERAGE) OF THE SQUARES OF EACH SMALL INCREMENT OF THE WAVEFORM. SO, IN PRACTICE, RMS MEANS EQUIVALENT TO DC.

D

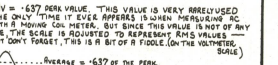
PEAK — THE PEAK VALUE IS THE MAXIMUM (AND MINIMUM AS SHOWN) VALUE OF THE WAVEFORM.



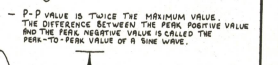
AVERAGE — Av = ·637 PEAK VALUE. THIS VALUE IS VERY RARELY USED THE ONLY TIME IT EVER APPEARS IS WHEN MEASURING RC WITH A MOVING COIL METER. BUT SINCE THIS VALUE IS NOT OF ANY USE, THE SCALE IS ADJUSTED TO REPRESENT RMS VALUES — BUT DON'T FORGET, THIS IS A BIT OF A FIDDLE (ON THE VOLTMETER SCALE)



PEAK-TO-PEAK — P-P VALUE IS TWICE THE MAXIMUM VALUE. THE DIFFERENCE BETWEEN THE PEAK POSITIVE VALUE AND THE PEAK NEGATIVE VALUE IS CALLED THE PEAK-TO-PEAK VALUE OF A SINE WAVE.

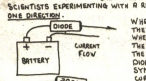


RMS VALUE — THE RMS VALUE CAN BE CALLED THE "EFFECTIVE" VALUE. IN OTHER WORDS, WE CAN SAY RMS VALUE IS THE EQUIVALENT TO DC, VALUE.

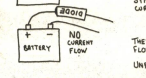


A ELECTRON FLOW

DURING EXPERIMENTATION EVERYONE MAKES MISTAKES ONE UNFORTUNATE MISTAKE OCCURED 50 YEARS AGO (MMXO) SCIENTISTS EXPERIMENTING WITH A RECTIFIER, DIODE FOUND IT CONDUCTED IN ONLY ONE DIRECTION.



WHEN THEY PLACED IT IN THE POSITIVE LINE THEY FOUND THAT CURRENT WOULD FLOW WHEN IT WAS REVERSED, NO CURRENT WOULD FLOW THEY CONCLUDED THAT CURRENT FLOWS OUT THE POSITIVE TERMINAL AND THROUGH THE DIODE. THUS THEY GAVE THE DIODE AN 'ARROW' SYMBOL SHOWING THE DIRECTION OF THE CURRENT FLOW:



THEY CREATED THE CONVENTION THAT ELECTRICITY FLOWS FROM POSITIVE TO NEGATIVE.

UNFORTUNATELY THEY WERE WRONG!

ELECTRICITY IS MADE UP OF ELECTRONS AND THESE FLOW FROM NEGATIVE TO POSITIVE. THUS ELECTRICITY DOES NOT FLOW IN THE DIRECTION OF THE ARROW.

THIS HAS CREATED 2 SCHOOLS OF REASONING, ONE CALLED 'CONVENTIONAL CURRENT' & THE OTHER "ELECTRON FLOW". "CONVENTIONAL CURRENT" APPLIES TO ELECTRICAL WORK AND ELECTRICIANS

ELECTRICAL WORK: CURRENT — "CONVENTIONAL CURRENT FLOW"

FOR LAMPS, SWITCHES, MOTORS ETC.

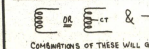
ELECTRONIC WORK: ELECTRON FLOW — "ELECTRON FLOW"

ELECTRONS FLOW AGAINST THE ARROW OF THE SYMBOL OF THE DIODE

FOR DIODES, TRANSISTORS ETC

WE USE ELECTRON FLOW IN OUR:

3 BASIC POWER SUPPLY CIRCUITS

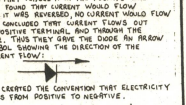


COMBINATIONS OF THESE WILL GIVE 3 DIFFERENT CIRCUITS.

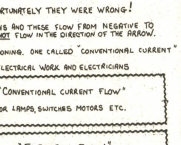
B THE 3 POWER SUPPLY CIRCUITS ARE:

1. HALF-WAVE ..... WITH 1 DIODE
2. FULL-WAVE WITH CENTRE-TAP TRANSFORMER..... WITH 2 DIODES
3. FULL-WAVE BRIDGE RECTIFIER..... WITH 4 DIODES

1. HALF WAVE RECTIFIER


CATHODE
THIS LINE WILL BECOME POSITIVE
AC MAINS
DIODE
LOAD
OUTPUT VOLTAGE = V_{OUT}
VOLTAGE OF SECONDARY WINDING = $V_{SECONDARY}$
THIS LINE IS CALLED "EARTH" OR "CHASSIS" IT SOMETIMES HAS AN EARTH SYMBOL

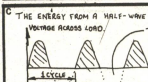
HOW THE CIRCUIT WORKS


WHEN THIS END OF THE DIODE IS RAISED HIGHER THAN THE OTHER END IT BEGINS TO CONDUCT ELECTRONS IN THIS DIRECTION
DURING CONDUCTION THERE WILL BE A VOLTAGE OF -7v ACROSS THE DIODE.
ELECTRONS FLOW THIS WAY
THIS END WILL BE POSITIVE
-7v
DURING THIS PERIOD OF TIME THE TOP OF THE SECONDARY WINDING IS POSITIVE & THE BOTTOM IS NEGATIVE THIS IS WHEN THE DIODE WILL CONDUCT.
0v
THE OUTPUT FROM THE SECONDARY IS AN EXACT MINIATURE OF THE "MAINS" THE * SHOWS THE START OF THE WINDING.
THE INPUT WAVEFORM FROM THE "MAINS"
ELECTRON FLOW
LOAD
VOLTAGE ACROSS LOAD
THE LOAD WILL RECEIVE PULSES OF POWER, LIKE THIS
TIME
THE DIODE DOES NOT CONDUCT DURING THIS TIME INTERVAL.
DURING THIS PERIOD, THE DIODE CONDUCTS

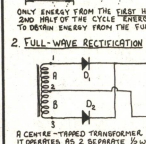
C THE ENERGY FROM A HALF-WAVE RECTIFIER LOOKS LIKE THIS:

ONLY ENERGY FROM THE FIRST HALF OF EVERY CYCLE IS OBTAINED. DURING THE 2ND HALF OF THE CYCLE "ENERGY" IS NOT DRAWN FROM THE MAINS. TO OBTAIN ENERGY FROM THE FULL CYCLE, WE NEED TO LOOK AT:

2. FULL-WAVE RECTIFICATION



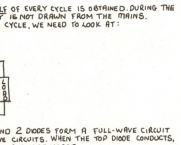
A CENTRE-TAPPED TRANSFORMER AND 2 DIODES FORM A FULL-WAVE CIRCUIT IT OPERATES AS 2 SEPARATE ½-WAVE CIRCUITS. WHEN THE TOP DIODE CONDUCTS, THE LOWER DIODE IS NON-CONDUCTING AND VISE VERSA.



THE TWO DIAGRAMS REPRESENT 1 FULL CYCLE. NOTICE THE ELECTRONS FLOW THROUGH THE LOAD IN THE SAME DIRECTION FROM EACH HALF CYCLE. A FULL WAVE CIRCUIT DELIVERS 2 PULSES OF ENERGY DURING EACH CYCLE

D 3 FULL WAVE BRIDGE RECTIFIER

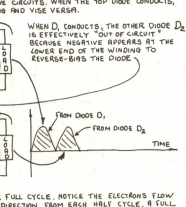
REMEMBER: ALL THE DIODES FACE IN THE GENERAL DIRECTION OF:



FOR THIS REASON WE SOMETIMES SEE THE SYMBOL FOR A BRIDGE AS:

A FULL WAVE CIRCUIT CAN BE MADE BY USING A SINGLE SECONDARY WINDING AND 4 DIODES. THESE ARE ARRANGED IN A BRIDGE AS SHOWN ABOVE.

THE OPERATION OF THE CIRCUIT IS BEST SHOWN IN 2 STAGES :



WHEN THE TOP OF THE WINDING IS POSITIVE, DIODES D_2 & D_4 ARE FORWARD BIASED AND SUPPLY THE LOAD WITH ENERGY.

DIODES D_1 & D_3 ARE REVERSE BIASED AND ARE EFFECTIVELY 'OUT OF CIRCUIT'.

NOTE: EVEN THOUGH THE POLARITY IS CHANGING FROM THE SECONDARY WINDING, THE ENERGY IS PASSING THROUGH THE LOAD IN ONLY ONE DIRECTION.

*THESE ARE ONLY SKETCHES.

D_2 & D_4 SUPPLY THIS ENERGY

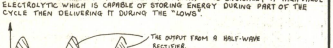
D_1 & D_3 SUPPLY THIS ENERGY

ALL THE RECTIFIER CIRCUITS 1, 2 & 3 PRODUCE PULSATING DC AND IT MUST BE SMOOTHED BEFORE IT IS SUITABLE FOR AN ELECTRONIC CIRCUIT

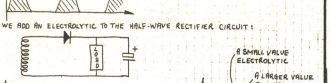
A

FILTERS

A FILTER SMOOTHS PULSATING DC FROM EITHER A HALF-WAVE RECTIFIER OR A FULL-WAVE RECTIFIER. IT IS BASICALLY A HIGH-VALUE ELECTROLYTIC WHICH IS CAPABLE OF STORING ENERGY DURING PART OF THE CYCLE THEN DELIVERING IT DURING THE "LOWS".

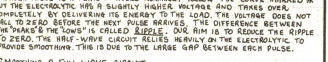


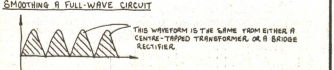
IF WE ADD AN ELECTROLYTIC TO THE HALF-WAVE RECTIFIER CIRCUIT:



THE TRANSFORMER & DIODE SUPPLY A VERY HEAVY CURRENT FOR THIS PERIOD OF TIME AS THEY ARE SUPPLYING THE LOAD & CHARGING THE ELECTROLYTIC. ONCE THE VOLTAGE RISES TO A PEAK, IT WOULD NORMALLY FOLLOW THE CURVE MARKED * BUT THE ELECTROLYTIC HAS A SLIGHTLY HIGHER VOLTAGE AND TAKES OVER, COMPLETELY, BY DELIVERING ITS ENERGY TO THE LOAD. THE VOLTAGE DOES NOT FALL TO ZERO BEFORE THE NEXT PULSE ARRIVES. THE DIFFERENCE BETWEEN THE "PEAKS & THE "LOWS" IS CALLED RIPPLE. OUR AIM IS TO REDUCE THE RIPPLE TO ZERO. THE HALF-WAVE CIRCUIT RELIES HEAVILY ON THE ELECTROLYTIC TO PROVIDE SMOOTHING - THIS IS DUE TO THE LARGE GAP BETWEEN EACH PULSE.

SMOOTHING A FULL-WAVE CIRCUIT

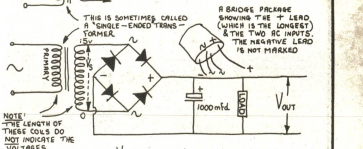




B

WHEN AN ELECTROLYTIC IS INCLUDED IN THE POWER SUPPLY CIRCUIT WE OBTAIN A DC VOLTAGE WHICH CAN BE USED TO OPERATE NON-CRITICAL EQUIPMENT SUCH AS TRANSISTOR RADIOS, CB RADIOS, ELECTRIC MOTORS ETC. THIS VOLTAGE STILL CONTAINS SOME NOTICEABLE RIPPLE.

THE OUTPUT OF THIS POWER SUPPLY WILL BE HIGHER THAN THE RMS RATING OF THE TRANSFORMER DUE TO THE RECTIFYING & SMOOTHING STAGES. THE RELATIONSHIP BETWEEN THE OUTPUT OF THE TRANSFORMER AND THE FINAL DC VOLTAGE IS FOUND IN THE FOLLOWING MANNER:


AC INPUT
15v
THIS IS THE RMS VOLTAGE OF THE TRANSFORMER AS SUPPLIED BY THE MANUFACTURER. (WHEN THE TRANSFORMER IS SUPPLYING ITS RATED CURRENT).
THIS IS SOMETIMES CALLED A "SINGLE-ENDED TRANSFORMER
A BRIDGE PACKAGE SHOWING THE + LEAD (WHICH IS THE LONGEST) & THE TWO AC INPUTS. THE NEGATIVE LEAD IS NOT MARKED
PRIMARY
SECONDARY
15v
0
15v
1000 mfd.
LOAD
V_{OUT}

NOTE: THE LENGTH OF THESE COILS DO NOT INDICATE THE VOLTAGES.

$$V_{OUT} = 1{\cdot}41 \times V_{SECONDARY}$$
$$= 1{\cdot}41 \times 15$$
$$= 21{\cdot}2 \text{ VOLTS.}$$

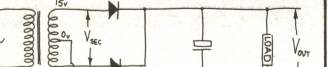
THERE IS A VOLTAGE DROP OF ·6V ACROSS EACH DIODE & SINCE 2 DIODES ARE IN CIRCUIT AT ANY PARTICULAR TIME, THE VOLTAGE LOST = 1·2V.

$\therefore$ ACTUAL VOLTAGE OUT = 21·2 − 1·2

= 20 VOLTS.

* THIS SHOWS WE ARE OBTAINING VERY NEARLY THE PEAK VOLTAGE OF THE WINDING. IF WE ARE DRAWING 1 AMP FROM THIS SUPPLY, IT IS DELIVERING 21·2 × 1 = 21·2 WATTS. THIS MEANS THE 15v AC WINDING IS SUPPLYING $\frac{21{\cdot}2}{15}$ = 1·41 AMPS (THIS IS A FACT WORTH REMEMBERING.)

C



IF YOU USE A CENTRE-TAPPED TRANSFORMER

$$V_{OUT} = \cdot 71 \times V_{SEC}$$
$$= \cdot 71 \times 30 \text{ "}$$
$$= 21{\cdot}2 \text{ VOLTS.}$$

THIS IS EXACTLY THE SAME RESULT AS THE SINGLE-ENDED POWER SUPPLY. BUT SINCE ONLY ONE DIODE IS IN CIRCUIT AT A TIME, THE VOLTAGE LOST ACROSS THE RECTIFIER IS ONLY ·6V.

$\therefore$ ACTUAL V_{OUT} = 21·2 − ·6

= 20·6 VOLTS.

WHICH CIRCUIT IS BEST?

THE CENTRE-TAPPED CIRCUIT HAS SOME ADVANTAGES OVER THE FULL-WAVE BRIDGE-RECTIFIER CIRCUIT.

DURING EACH CYCLE THE FULL-WAVE BRIDGE RECTIFIER HAS 2 OF ITS FOUR DIODES IN CIRCUIT. THIS WILL REDUCE THE OUTPUT VOLTAGE BY 1·2 VOLTS. FOR THE CENTRE-TAPPED CIRCUIT, ONLY ONE DIODE IS CONDUCTING DURING EACH CYCLE & THE LOSS WILL BE ·6v. THUS THE LOSS WILL BE ONLY THAT OF THE 4-DIODE BRIDGE RECTIFIER CIRCUIT.

THIS CAN BE QUITE CONSIDERABLE FOR HIGH-CURRENT SITUATIONS WHERE THE DIODES ARE REQUIRED TO BE HEATSINKED.—ONLY HALF THE HEAT-SINK AREA WILL BE NEEDED.

IN THE CENTRE-TAPPED CIRCUIT, EACH WINDING WILL BE SUPPLYING CURRENT FOR 50% OF THE TIME & THE WIRE SIZE WOULD BE SMALLER THAN FOR A SINGLE-ENDED TRANSFORMER. (BUT THE TOTAL WEIGHT OF THE 2 WINDINGS WILL EQUAL THAT OF THE OTHER TRANSFORMER).

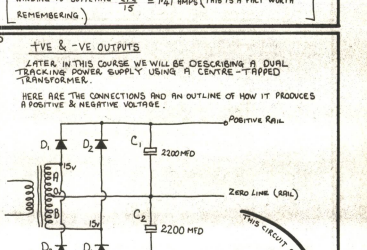
ALSO THE WINDINGS CAN BE WOUND ON THE TRANSFORMER IN 2 DIFFERENT SECTIONS, REDUCING THE HEAT BUILD-UP. HOWEVER THIS IS NOT EXCLUSIVE TO THE CENTRE-TAPPED TRANSFORMER AS A SINGLE-ENDED TYPE CAN ALSO BE SPREAD OUT.

D

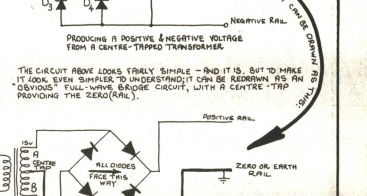
+VE & -VE OUTPUTS

LATER IN THIS COURSE WE WILL BE DESCRIBING A DUAL TRACKING POWER SUPPLY USING A CENTRE-TAPPED TRANSFORMER.

HERE ARE THE CONNECTIONS AND AN OUTLINE OF HOW IT PRODUCES A POSITIVE & NEGATIVE VOLTAGE.

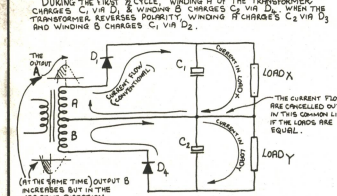


THE CIRCUIT ABOVE LOOKS FAIRLY SIMPLE — AND IT IS. BUT TO MAKE IT LOOK EVEN SIMPLER, TO UNDERSTAND; IT CAN BE REDRAWN AS AN "OBVIOUS" FULL-WAVE BRIDGE CIRCUIT, WITH A CENTRE-TAP PROVIDING THE ZERO (RAIL).



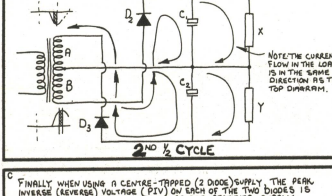
A

During the first ½ cycle, winding A of the transformer charges C_1 via D_1 & winding B charges C_2 via D_4. When the transformer reverses polarity, winding A charges C_2 via D_3 and winding B charges C_1 via D_2.



1ST ½ CYCLE

For the first ½ cycle (the electros are completely discharged) the output of winding A charges C_1 & & charges C_2. Diode D_1 is forward biased for the increasing negative voltage & thus C_2 is charged up.



Note the current flow in the load is in the same direction as the top diagram.

2ND ½ CYCLE

B

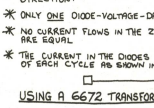
During the second ½ cycle the diode do not begin to conduct until the output of the transformer is nearing its maximum voltage. This is due to the electrolytic storing some of the charge from the first ½ cycle.

POINTS TO NOTE:

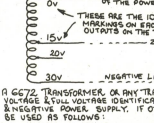
- Winding A firstly charges C_1 then C_2 during one complete cycle.
- Even though the transformer output is changing direction, the current flowing in the load is always in the one direction.
- Only one diode-voltage-drop is lost in each circuit.
- No current flows in the zero voltage line if the loads are equal
- The current in the diodes flows only during a fraction of each cycle as shown in the small diagrams.

USING A 6672 TRANSFORMER

0v, 15v, 17.5v, 20v, 24v, 27.5v, 30v @ 1 AMP



A 6672 transformer, or any transformer having zero voltage, half voltage & full voltage identification can be used to make a positive & negative power supply. If other taps are available they can be used as follows:



We could label a 6672 as 15v-0-15v as all outputs are AC and each is relative to which tap we call zero.

If we place a diode & electro as shown, we obtain a -7v output. This will be used in a later discussion to adjust a 7805 regulator down to zero volts output.

C

Finally when using a centre-tapped (2 diode) supply, the peak inverse (reverse) voltage (PIV) on each of the two diodes is twice the PIV for the 4-diode bridge rectifier supply. This becomes a design consideration when the voltage is nearing the maximum PIV rating of the diodes.

PIV RATING: The rating of a diode such as IN4002 is given as: 100v @ 1amp. This is its forward-voltage rating & continuous current rating. It is capable of withstanding a reverse-voltage of 120% or 120v.

Using a 15v transformer the PIV rating for the 2 diodes must be more than:

Twice × 15v × 1·41 = 42·5volts.

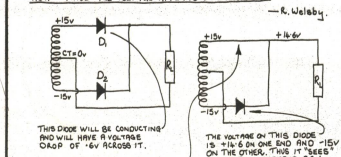
For a 4-diode bridge rectifier, each diode must have a rating greater than:

One × 15v × 1·41 = 21·2 volts

This shows that the reverse voltage is a lot higher than the output voltage of the power supply.

HOW "TWICE" THE VOLTAGE APPEARS ON EACH DIODE

—R. Walsby.


+15v
CT=0v
-15v
D_1
D_2
R
This diode will be conducting and will have a voltage drop of ·6v across it.
This voltage drop is so small that we can almost neglect it when considering the voltage across the lower diode.
+15v
+14·4v
R
-15v
The voltage on this diode is +14·6 on one end and -15v on the other. This it "sees" or has to withstand 29·4v and this is in the reverse direction to its normal operation.

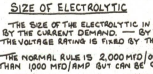
The same reasoning applies when the transformer (voltage) reverses direction & the top winding becomes -15v. The top diode will be reverse biased to 29·4 volts.

D

SIZE OF ELECTROLYTIC

The size of the electrolytic in a power supply is determined by the current demand. By "size" we mean its value in mfd. The voltage rating is fixed by the output voltage of the transformer.

The normal rule is 2,000 mfd/output amp. It should not be less than 1000 mfd/amp but can be greater.



A 1000 mfd electrolytic @ 16 volts (working)

A 4,400 mfd set-up.

A 100,000 mfd !

An electrolytic will reduce the ripple to a low level. But this simple form of smoothing is not nearly good enough for electronic equipment with ripple values as low as 1v P-P we will be able to hear an annoying hum in the background of amplifiers or see a distorted picture gradually moving down the screen on video monitors. In digital circuits this low-level ripple will give rise to false triggering.

To reduce the ripple even further, we have the choice of 3 filters:

1. Resistance — capacitance network (R-C network)
2. Inductance — capacitance network (L-C network)
3. An electronic filter.

The first two of these filters are very big and bulky. They are also very expensive. They waste a lot of power, and do not achieve a very good result. They have almost entirely disappeared with the introduction of the regulator chip. These solid state wonders — such as the 7805 — look very similar to a transistor, and produce a very high degree of electronic smoothing. — So R-C & L-C is out.

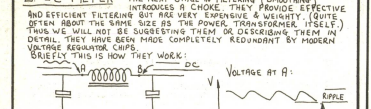
The main requirement for a filter electrolytic is to prevent the input voltage to a regulator dropping below its output voltage. In fact it should be at least 3v higher than the output so that the regulator can maintain regulation.

Take this example: A 7805 is designed to produce a fixed output of 5v. The minimum input voltage for this device is 8v. If the input voltage drops 1v on full load, the input voltage must be at least 9v at zero current.

A 2. LC FILTER

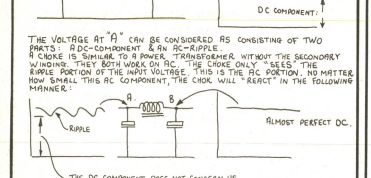
THE NEXT STAGE IN FILTERING (SMOOTHING) INTRODUCES A CHOKE. THIS PROVIDES EFFECTIVE AND EFFICIENT FILTERING BUT ARE VERY EXPENSIVE & WEIGHTY. (QUITE often about the same size as the power transformer itself.) THUS WE WILL NOT BE SUGGESTING THEM OR DESCRIBING THEM IN DETAIL THEY HAVE BEEN MADE COMPLETELY REDUNDANT BY MODERN VOLTAGE REGULATOR CHIPS.

BRIEFLY THIS IS HOW THEY WORK:



THE VOLTAGE AT "A" CAN BE CONSIDERED AS CONSISTING OF TWO PARTS: A DC-COMPONENT & AN AC-RIPPLE.

A CHOKE IS SIMILAR TO A POWER TRANSFORMER WITHOUT THE SECONDARY WINDING. THEY BOTH WORK ON AC. THE CHOKE ONLY "SEES" THE RIPPLE PORTION OF THE INPUT VOLTAGE. THIS IS THE AC PORTION. NO MATTER HOW SMALL THIS AC COMPONENT, THE CHOK WILL "REACT" IN THE FOLLOWING MANNER:



TOWARDS THE TOP OF THE WAVEFORM THE "RATE OF CHANGE OF VOLTAGE" IS REDUCED AND THUS THE MAGNETIC FLUX CANNOT BE MAINTAINED. THE FLUX BUILT UP IN THE CORE BEGINS TO TAKE OVER AND SINCE THIS IS IN THE OPPOSITE DIRECTION, PRODUCES A VOLTAGE WHICH IS IN OPPOSITION. THUS THE VOLTAGE PEAKS ARE REDUCED DRAMATICALLY IN SIMPLE TERMS, THE EXCESS ENERGY OBTAINED FROM THE PEAKS IS ABSORBED BY THE CHOKE AND DELIVERED INTO THE "TROUGHS" (LOWS).

B

NOTES: 1. A CHOKE THE SAME SIZE AS THE POWER TRANSFORMER WILL SMOOTH 100 TIMES BETTER THAN AN R-C NETWORK.

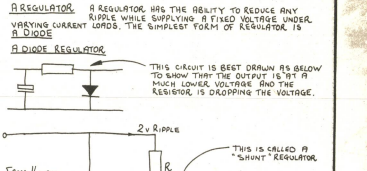
2. THE VOLTAGE DROP ACROSS A CHOKE WILL BE 1/10 THAT OF AN R-C NETWORK.

3. CHOKES ARE VERY EXPENSIVE AND HEAVY AND ALMOST UNOBTAINABLE.

CHOKE SMOOTHING AND RESISTOR SMOOTHING HAVE GONE OUT OF FAVOUR FOR A NUMBER OF REASONS. APART FROM THE COST AND SIZE, MOST EQUIPMENT REQUIRES A FIXED VOLTAGE AS WELL AS VERY LITTLE AC COMPONENT, SUCH AS 12V ±1V AT 10V RIPPLE OR 35V ±3V @ 1V RIPPLE. THIS MEANS THE 12V CIRCUIT DOES NOT WANT MORE THAN 13V OR LESS THAN 11V. FOR EXAMPLE A 12V PORTABLE TV WILL OVER-SCAN THE PICTURE IF FED 13V OR WILL HAVE LACK OF HEIGHT AT 11V KEEPING THE VOLTAGE AT 12V.±1 IS CALLED REGULATION. A CHOKE OR RESISTOR SMOOTHING DOES NOT PROVIDE ANY REGULATION AND THUS HAS ONLY LIMITED USE.

A REGULATOR A REGULATOR HAS THE ABILITY TO REDUCE ANY RIPPLE WHILE SUPPLYING A FIXED VOLTAGE UNDER VARYING CURRENT LOADS. THE SIMPLEST FORM OF REGULATOR IS A DIODE

A DIODE REGULATOR


THIS CIRCUIT IS BEST DRAWN AS BELOW TO SHOW THAT THE OUTPUT IS 9V A MUCH LOWER VOLTAGE AND THE RESISTOR IS DROPPING THE VOLTAGE.
2v RIPPLE
R
THIS IS CALLED A "SHUNT" REGULATOR.
FROM ½ WAVE OR FULL-WAVE RECTIFIER.
C1
ABOUT ½V RIPPLE.
K
*65V OUTPUT.

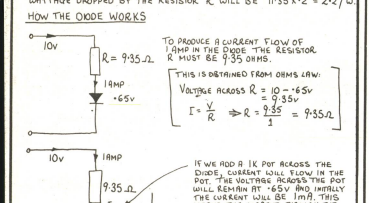
DIODE

A SINGLE PLACED AS ABOVE WILL PRODUCE AN OUTPUT OF *65V. EVEN IF THE VOLTAGE FROM THE RECTIFIER IS 6V 12V OR 35V. THE DIFFERENCE BETWEEN *65V AND SAY 12V IS DROPPED IN THE RESISTOR R AND THIS CAN BE A VERY WASTEFUL CIRCUIT AS YOU WILL SEE.

C

FOR AN OUTPUT CURRENT OF 1AMP @ *65V AND WITH A SUPPLY VOLTAGE OF 12V FROM THE RECTIFIER DIODE. THE RESISTOR R WILL DROP 11·35V AND WILL DISSIPATE 11·35 x 1 AMP = 11·35 WATTS. THE WATTAGE AVAILABLE AT THE OUTPUT TERMINALS = *65 x 1 AMP = *65 WATTS. THUS MOST OF THE POWER IS BEING LOST. IF WE ONLY WISH THE ORIGINAL *2AMP FROM THE OUTPUT, THE VOLTAGE WILL REMAIN AT *65 AND THE WATTAGE DROPPED IN THE RESISTOR R WILL BE 11·35 x 2 = 2·27 W.

HOW THE DIODE WORKS


10v
R = 9·35Ω
1 AMP
*65v
TO PRODUCE A CURRENT FLOW OF 1 AMP IN THE DIODE THE RESISTOR R MUST BE 9·35 OHMS.
THIS IS OBTAINED FROM OHMS LAW:
VOLTAGE ACROSS R = 10 − *65V = 9·35V
I = V/R ⇒ R = 9·35/1 = 9·35Ω
10v
1 AMP
9·35Ω
I=
*65v
1K POT
IF WE ADD A 1K POT ACROSS THE DIODE, CURRENT WILL FLOW IN THE POT. THE VOLTAGE ACROSS THE POT WILL REMAIN AT *65V AND INITIALLY THE CURRENT WILL BE 1mA. THIS MEANS THE CURRENT THROUGH THE DIODE IS 999 mA. AS THE CURRENT THROUGH THE POT INCREASES IT IS "TAKEN" FROM THE DIODE THE DIODE HAS THIS AMAZING ABILITY. FINALLY THE CURRENT THROUGH THE POT WILL BE 999 mA AND ONLY 1mA WILL BE FLOWING THROUGH THE DIODE.

AS SOON AS YOU DRAW 1001 mA THROUGH THE POT, THE DIODE WILL NOT BE PASSING ANY CURRENT AND REGULATION WILL BE LOST. THE OUTPUT VOLTAGE WILL DROP TO *64V OR LOWER, AND THE DIODE WILL CEASE TO HAVE ANY EFFECT.

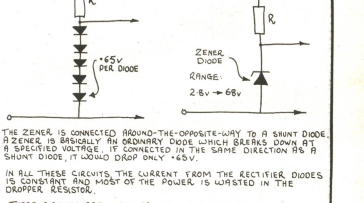
IN SUMMARY FOR A CURRENT FLOW THROUGH THE DIODE — FROM A FEW MILLIAMPS TO 1 AMP — THE OUTPUT WILL REMAIN CLOSE TO *65V.

THUS WE HAVE ACHIEVED 2 FUNCTIONS:

1. SMOOTHING — ANY RIPPLE IN THE INPUT WILL BE REMOVED
2. VOLTAGE STABILISATION — THE OUTPUT WILL REMAIN AT *65V FOR VARYING CURRENT DEMAND.

D

TO INCREASE THE OUTPUT VOLTAGE WE CAN USE A NUMBER OF DIODES AS SHOWN IN THE DIAGRAM OR USE A ZENER DIODE.



THE ZENER IS CONNECTED AROUND-THE-OPPOSITE-WAY TO A SHUNT DIODE. A ZENER IS BASICALLY AN ORDINARY DIODE WHICH BREAKS DOWN AT A SPECIFIED VOLTAGE. IF CONNECTED IN THE SAME DIRECTION AS A SHUNT DIODE, IT WOULD DROP ONLY *65V.

IN ALL THESE CIRCUITS, THE CURRENT FROM THE RECTIFIER DIODES IS CONSTANT AND MOST OF THE POWER IS WASTED IN THE DROPPER RESISTOR.

THESE CIRCUITS ARE VERY WASTEFUL AND THUS VERY INEFFICIENT.

THE FOLLOWING SIX PROBLEMS CAN BE SOLVED.....

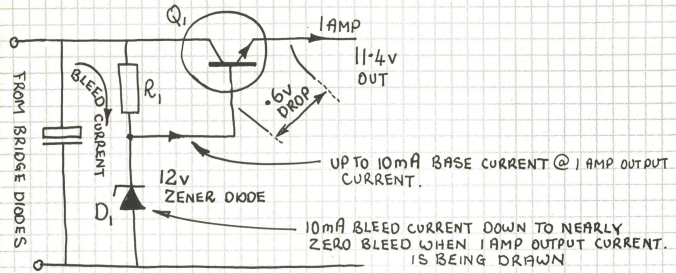
- REGULATION — KEEPING THE VOLTAGE CONSTANT
- SMOOTHING — REDUCING THE RIPPLE
- EFFICIENCY — REDUCING HEAT LOSSES
- WEIGHT — KEEPING THE WEIGHT DOWN
- COST — " " COST "
- SIZE — " " SIZE "

..... WITH AN ELECTRONIC FILTER.

3 ELECTRONIC FILTER:

WE HAVE SEEN HOW A DIODE CAN PERFORM 2 FUNCTIONS BY ITSELF, BUT VERY INEFFICIENTLY. TO MAKE IT *100 TIMES MORE EFFECTIVE WE CAN COMBINE IT WITH A TRANSISTOR IN A SERIES REGULATOR CIRCUIT TO PRODUCE AN ELECTRONIC FILTER.

SIMPLE SERIES REGULATOR:



NOTES:

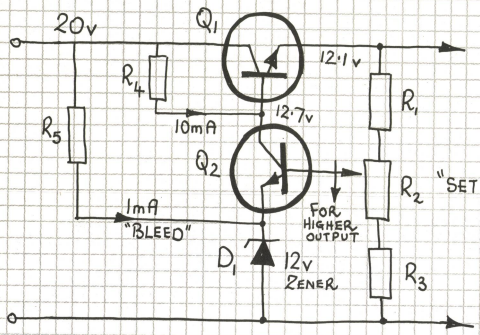
* R_1 & D_1 FORM A SHUNT REGULATOR
* D_1 IS A ZENER DIODE
* D_1 MUST NEVER BE TAKEN OUT OF BREAK-DOWN OR REGULATION WILL BE LOST IE. IT MUST ALWAYS PASS A BLEED CURRENT.
* R_1 & D_1 ARE DESIGNED TO PASS 10 OR 11 mA
* THUS 10mA IS AVAILABLE FOR THE BASE CURRENT.
* Q_1 HAS A GAIN OF 100 TIMES (AS PER DATA SHEET) 10mA x 100 = 1,000mA = 1 AMP THUS THE REGULATOR WILL SUPPLY 1 AMP TO THE LOAD.
* Q_1 HAS A VOLTAGE DROP OF ·6v FROM BASE TO EMITTER THUS IF ZENER VOLTAGE IS 12v THE OUTPUT VOLTAGE WILL BE 12 − ·6 = 11·4v.

IN THIS 1 AMP POWER SUPPLY ONLY 10mA "BLEED CURRENT" IS LOST THIS IS 100TIMES MORE EFFICIENT THAN USING JUST A DIODE. THE VOLTAGE REGULATION IS OBTAINED FROM THE ZENER DIODE THE TRANSISTOR AMPLIFIES THE CURRENT CAPABILITIES OF THE DIODE BY 100 TIMES.

THIS POINT NEEDS TO BE UNDERSTOOD. IF WE DRAW TOO MUCH CURRENT OUT OF THE CIRCUIT THE BASE WILL DRAW MORE THAN 10mA THROUGH R_1 BUT THIS WOULD DIMINISH THE CURRENT THROUGH THE ZENER DIODE TO ZERO AND REGULATION WOULD BE LOST.

THE ABOVE CIRCUIT IS ONLY CAPABLE OF A FIXED OUTPUT VOLTAGE. THIS VOLTAGE IS MAINTAINED OVER 0 → 1 AMP RANGE. BY SELECTING A SUITABLE VALUE OF ZENER DIODE AND ADDING AN "ERROR SENSING" TRANSISTOR WE CAN VARY THE OUTPUT VOLTAGE FROM THE ZENER-VOLTAGE TO SLIGHTLY LESS THAN THE INPUT VOLTAGE. (FOR GOOD SMOOTHING Q_1 SHOULD DROP AT LEAST 4 → 5 VOLTS).

SERIES REGULATOR WITH ADJUSTABLE OUTPUT VOLTAGE



THE CIRCUIT STARTS UP AS FOLLOWS (TAKEN IN SLOW MOTION)

Q_1 IS A 12v ZENER DIODE THE 20v INPUT FEEDS THE DIODE VIA R_5. R_4 PROVIDES TURN-ON VOLTAGE FOR Q_1. R_1 R_2 & R_3 PROVIDE A VOLTAGE DIVIDER NETWORK TO TURN ON Q_2.
WHEN POWER IS APPLIED, R_4 PROVIDES THE BASE OF Q_1 WITH ALMOST FULL INPUT VOLTAGE TO TURN IT ON. AS THE EMITTER VOLTAGE RISES (ACTUALLY IT FOLLOWS THE COLLECTOR VOLTAGE) THE VOLTAGE DIVIDER NETWORK CONSISTING OF R_1 R_2 & R_3 WILL PRODUCE A VOLTAGE AT THE BASE OF Q_2. Q_2 WILL BE FULLY TURNED ON AT 12·6v AND THE COLLECTOR OF Q_2 WILL BE 12·7v. (WHICH IS THE ZENER VOLTAGE PLUS THE COLLECTOR—EMITTER VOLTAGE DROP) THE OUTPUT OF Q_1 WILL BE ·6v LOWER THAN THIS AT 12·1 VOLTS.
THE CURRENTS FLOWING AT THIS STAGE WILL BE THE 1mA BLEED THROUGH R_5 10mA THROUGH THE TURN-ON RESISTOR R_4 & THE CURRENT THROUGH THE VOLTAGE DIVIDER NETWORK.
THE CIRCUIT WILL SUPPLY 0→1 AMP AS IN THE PREVIOUS CIRCUIT WITHOUT Q_2 PLAYING ANY FURTHER PART.
R_2 IS THE "SET OUTPUT VOLTS" AND ALLOWS THE OUTPUT TO BE ADJUSTED ABOVE 12·1 VOLTS TO 16VOLTS. R_2 IS INITIALLY SET AT THE TOP. AS THE SLIDER IS MOVED TOWARDS GROUND, Q_2 IS TURNED OFF AND Q_1 RECEIVES A HIGHER TURN-ON VOLTAGE VIA R_4. THE OUTPUT VOLTAGE RISES AND BEGINS TO TURN ON Q_2 AND THIS TURNS OFF Q_1 UNTIL A NEW OUTPUT VOLTAGE EQUILIBRIUM IS OBTAINED. THE CIRCUIT WILL NOW PROVIDE 0→1 AMPS AT THE NEW VOLTAGE WITHOUT Q_2 PLAYING ANY FURTHER PART.
THIS APPLIES TO THE QUIESCENT OR DC CONDITION. WHAT HAPPENS WHEN A RIPPLE VOLTAGE IS APPLIED TO THE CIRCUIT?

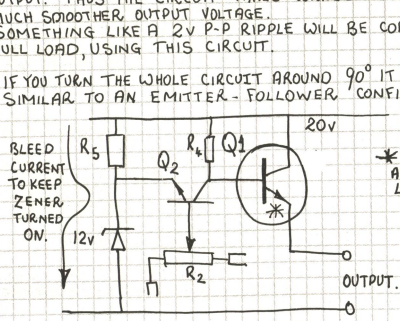
HOW A SERIES REGULATOR FILTERS RIPPLE

ANY RIPPLE APPEARING ON THE 20v LINE WILL EFFECTIVELY BE THE SAME AS RAISING THE INPUT VOLTAGE TO SAY 20·1v OR 20·4V. THIS INCREASED VOLTAGE IS NOT SENSED BY THE ZENER DIODE AS IT HAS A FIXED BREAKDOWN VOLTAGE OF 12V. SO THE ZENER BECOMES OUR BASE REFERENCE VOLTAGE. THE VOLTAGE INCREASE WILL BE SENSED BY Q2, THE ERROR SENSING TRANSISTOR.

THIS IS HOW IT WORKS:

THE ·1v OR ·4v RIPPLE PASSES THROUGH Q1 AND APPEARS AT THE OUTPUT AS 12·1v + ·1v OR 12·1v + ·4v = 12·2v TO 12·5v. R2 IS THE "OUTPUT VOLTS" POTENTIOMETER AND WILL BE SET TO PARTIALLY TURN ON Q2, TO PROVIDE THE ORIGINAL EQUILIBRIUM OF 12·1v. THE ·1v RIPPLE WILL TURN IT ON HARDER. THE VOLTAGE ON THE COLLECTOR WILL DECREASE & THIS WILL TURN Q2 VERY SLIGHTLY. THE EMITTER WILL FOLLOW THE BASE VOLTAGE BUT WILL BE ABOUT ·6V LESS. THIS ACTION OCCURS VERY RAPIDLY AND CAN FOLLOW A RIPPLE OF FAIRLY HIGH FREQUENCY SO THAT IT IS PREVENTED FROM APPEARING IN THE OUTPUT. THUS THE CIRCUIT TAKES CORRECTIVE ACTION TO RESULT IN A MUCH SMOOTHER OUTPUT VOLTAGE.
SOMETHING LIKE A 2v P-P RIPPLE WILL BE CORRECTED TO 20mV AT FULL LOAD, USING THIS CIRCUIT.

IF YOU TURN THE WHOLE CIRCUIT AROUND 90° IT WILL APPEAR VERY SIMILAR TO AN EMITTER-FOLLOWER CONFIGURATION:

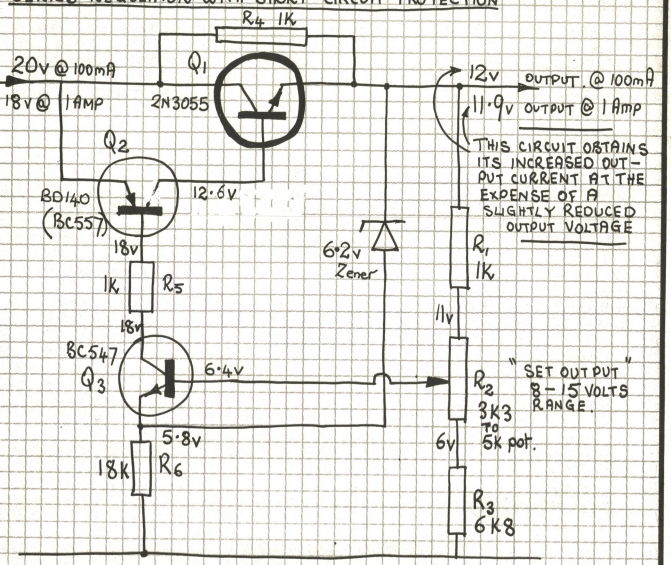


* THE EMITTER WILL ALWAYS BE ABOUT ·6V LESS THAN THE BASE.

IN THIS LAYOUT ARRANGEMENT IT MAY BE A LITTLE CLEARER TO SEE HOW Q2 IS ACTING LIKE A VARIABLE RESISTOR BETWEEN COLLECTOR AND EMITTER LEADS TO PROVIDE A BASE VOLTAGE FOR Q1. WHEN Q2 ACTS LIKE A LOW VALUE RESISTOR, THE BASE OF Q1 THINKS IT IS CONNECTED TO THE CATHODE OF THE 12v ZENER. IT THEN PROVIDES AN OUTPUT VOLTAGE OF 12v − ·6v = 11·4v WHEN Q2 IS A HIGH RESISTANCE THE BASE OF Q1 IS CONNECTED TO THE 20v RAIL AND THE OUTPUT IS 19·4v. IN ACTUAL OPERATION Q2 DOES NOT PROVIDE THIS WIDE A RANGE.

THIS CIRCUIT DOES SUFFER FROM ONE SLIGHT DISADVANTAGE. IT HAS NO OVER-LOAD PROTECTION OR SHORT-CIRCUIT PROTECTION. THE NEXT CIRCUIT ATTEMPTS TO FULFILL THESE CONDITIONS.

SERIES REGULATOR WITH SHORT-CIRCUIT PROTECTION



THIS CIRCUIT PROVIDES SHORT-CIRCUIT PROTECTION. IF THE OUTPUT IS SHORTED TO GROUND THE REGULATOR WILL SHUT DOWN LEAVING R4 AS THE ONLY SOURCE OF SUPPLY. FOR THIS REASON R4 SHOULD BE A 5WATT WIRE-WOUND RESISTOR — EVEN THOUGH IT DOES NOT SUPPLY ANY CURRENT WHEN THE POWER SUPPLY IS OPERATING CORRECTLY. THE ONLY OTHER TIME R4 IS NEEDED IS FOR STARTING UP. IT MUST PROVIDE ABOUT 1v INTO THE OUTPUT TO START-UP THE CIRCUIT. THE "SET OUTPUT" POT DETECTS ABOUT 50% OF THE OUTPUT VOLTAGE TO BEGIN TO TURN ON Q3. THIS WILL TURN ON THE POWER DRIVER TRANSISTOR Q2 WHICH WILL TURN ON THE POWER REGULATOR TRANSISTOR Q1. THIS CONDITION WILL INCREASE AND STABILIZE WITH THE OUTPUT AT 12v. AND ABOUT 100mA LOAD CURRENT. WHEN THE LOAD IS INCREASED TO 1AMP THE OUTPUT VOLTAGE REDUCES TO 11·9v WHICH EFFECTIVELY INCREASES THE BASE-EMITTER VOLTAGE OF Q1 TO ·7v TO TURN IT ON HARDER. THE INPUT VOLTAGE MAY REDUCE BY 2v OR SO BUT THE BASE VOLTAGE OF Q1 WILL REMAIN STABLE AT 12·6v.

OVERLOAD PROTECTION

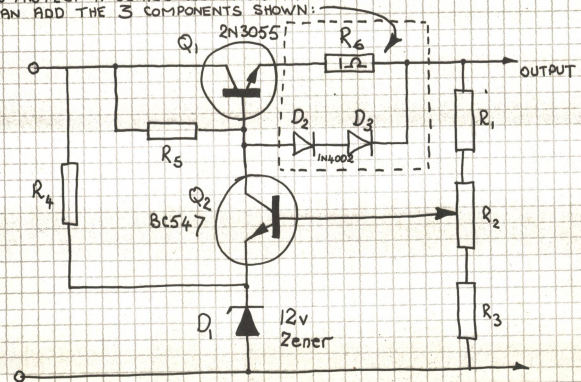
THE TWO PREVIOUS CIRCUITS PROVIDE 2 OUT OF 3 REQUIREMENTS FOR A GOOD POWER SUPPLY. THEY PROVIDE SMOOTHING & REGULATION (THE 2ND CIRCUIT ALSO HAS SHORT-CIRCUIT PROTECTION) THE 3RD IMPORTANT FEATURE TO BUILD INTO A POWER SUPPLY IS OVERLOAD PROTECTION. UP TO NOW THE ONLY FEATURE LIMITING THE MAXIMUM CURRENT IS THE CAPABILITY OF THE POWER TRANSFORMER AND THE CURRENT RATING OF THE POWER TRANSISTOR. A SHORT IN THE OUTPUT WILL ALLOW THE MAXIMUM TO BE UP TO 10TIMES THE NORMAL CURRENT & THIS WILL CAUSE OVERHEATING AND POSSIBLE DAMAGE TO MANY OF THE COMPONENTS.

OVERLOAD PROTECTION SHOULD ALWAYS BE INCORPORATED INTO POWER SUPPLIES DELIVERING MORE THAN 1 AMP. NOT ONLY WILL IT SAVE YOUR POWER SUPPLY FROM DESCRUCTION BUT PREVENT POSSIBLE FIRE RISK AND REDUCE FURTHER DAMAGE TO THE EQUIPMENT BEING SUPPLIED.

PROTECTION COMES IN TWO DIFFERENT FORMS. THE SIMPLEST IS TO PROVIDE A CIRCUIT BREAKER OR FUSE IN THE OUTPUT. THIS WILL BLOW WHEN THE CURRENT RISES APPROX 30% OVER THE RECOMMENDED MAX. ONCE TRIPPED, THE CIRCUIT WILL NOT RESET ITSELF AND REQUIRES MANUAL RESETTING, OR REPLACING THE FUSE. THE OBVIOUS DISADVANTAGE WITH THIS IS THE INCONVENIENCE OF PHYSICALLY CHANGING THE FUSE. IN ADDITION TO THE SMALL COST OF A FUSE, THE EQUIPMENT IS OUT OF ACTION FOR AN INDETERMINATE (UNKNOWN LENGTH) PERIOD OF TIME.

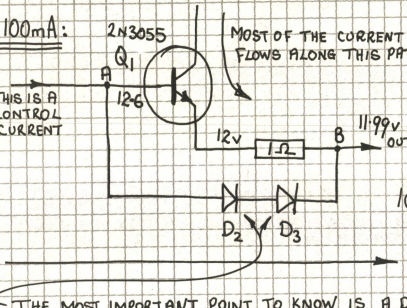
BEING ELECTRONICALLY MINDED, WE WOULDN'T TOLERATE THIS ARRANGEMENT FOR VERY LONG. SO AN ELECTRONIC OVERLOAD IS THE ANSWER.

TO PROTECT A SERIES REGULATOR FROM EXCESSIVE CURRENT OVERLOAD WE CAN ADD THE 3 COMPONENTS SHOWN:

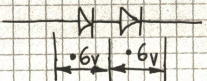


THE 1Ω RESISTOR IS IN SERIES WITH THE OUTPUT SO THAT ALL THE CURRENT FLOWS THROUGH IT. AS THE CURRENT INCREASES A VOLTAGE WILL BE DEVELOPED ACROSS THE RESISTOR ACCORDING TO OHMS LAW.

TURNING THE CIRCUIT AROUND 90° WILL MAKE THE OVERLOAD PROTECTION ARRANGEMENT EASIER TO FOLLOW:

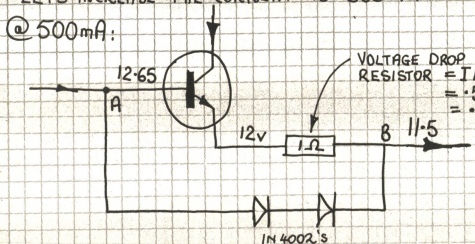


THE MOST IMPORTANT POINT TO KNOW IS A DIODE IN A FORWARD BIAS SITUATION WILL DROP A MAXIMUM OF ·6v. THUS WITH THESE



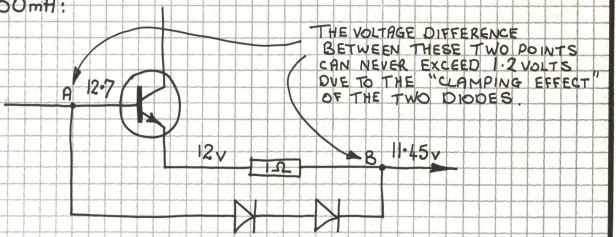
TWO DIODES THE MAXIMUM VOLTAGE THEY WILL ALLOW TO BE DEVELOPED ACROSS THEM IS 1·2 VOLTS. THIS MEANS THE MAXIMUM VOLTAGE BETWEEN POINTS A AND B WILL BE 1·2 VOLTS. (AT THE MOMENT IT IS ·61 VOLTS).

LETS INCREASE THE CURRENT TO 500 mA:



AT 500mA THE VOLTAGE BETWEEN POINTS A AND B HAS INCREASED TO 12·65 − 11·5 = 1·05 VOLTS. THIS IS STILL BELOW 1·2 VOLTS AND THUS THE DIODES DO NOT HAVE ANY EFFECT AT THIS CURRENT FLOW.

@ 550mA:



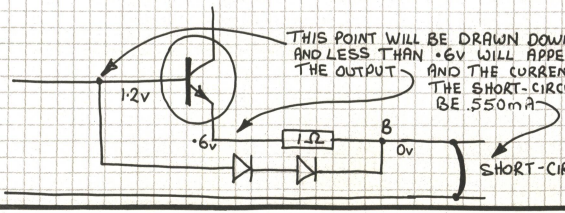
AT 550mA THE VOLTAGE LEVELS ARE SHOWN IN THE DIAGRAM ABOVE. THE TRANSISTOR HAS TURNED ON SLIGHTLY HARDER TO DELIVER THE CURRENT AND THIS HAS PRODUCED A VOLTAGE DIFFERENCE OF 12·7 − 11·45 = 1·25. NOW THIS IS GREATER THAN THE DIODES PERMIT AND ANY FURTHER ATTEMPT AT INCREASING THE CURRENT WILL LOWER THE OUTPUT DRAMATICALLY.
YOU SEE THE DIODES ARE NOW COMING INTO PLAY AS THE VOLTAGE ACROSS THEM HAS RISEN TO 1·2 VOLTS.

ANY INCREASE IN CURRENT WILL LOWER THE OUTPUT VOLTAGE (DUE TO THE VOLTAGE DROP ACROSS THE 1Ω RESISTOR) BUT THIS VOLTAGE WILL NOW BE PASSED STRAIGHT BACK TO THE BASE VIA THE DIODES AND THIS WILL TURN THE TRANSISTOR OFF. THIS WILL GIVE A LOWER OUTPUT VOLTAGE.

THE NET RESULT WILL BE A REDUCTION IN OUTPUT VOLTAGE SUCH THAT THE MAXIMUM CURRENT FLOWING WILL NOT EXCEED 550 mA.

[AS YOU KNOW A LOWER VOLTAGE APPLIED TO THE LOAD WILL RESULT IN A LOWER CURRENT FLOW — DUE TO OHMS LAW]

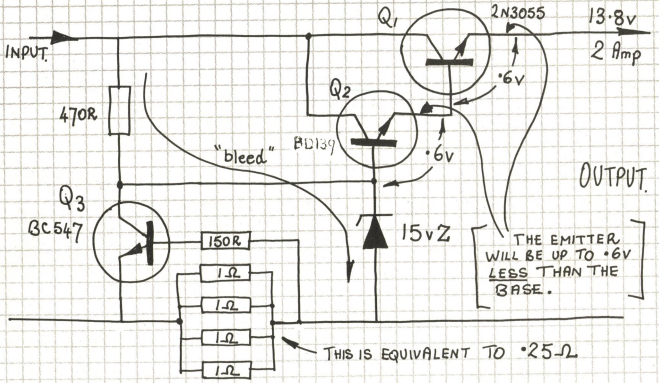
TAKE THE EXTREME CASE OF A SHORT-CIRCUIT:


THIS POINT WILL BE DRAWN DOWN TO 1·2v AND LESS THAN ·6v WILL APPEAR ON THE OUTPUT
AND THE CURRENT IN THE SHORT-CIRCUIT WILL BE .550mA
1·2v
·6v
1Ω
B
0v
SHORT-CIRCUIT.

THE MAIN DISADVANTAGE WITH THE PREVIOUS METHOD OF PROTECTING THE CIRCUIT AGAINST OVERLOAD WAS THE VOLTAGE DROP NEEDED TO OPERATE THE SENSING CIRCUIT. FROM NO-LOAD TO FULL-LOAD A ·5V REDUCTION IN VOLTAGE WAS INTRODUCED.

THIS STABILITY IS NOT GOOD ENOUGH FOR SOME EQUIPMENT. TAKE A TV SET FOR INSTANCE. SOME SETS ARE DESIGNED ON A RAIL VOLTAGE OF ONLY 11 VOLTS. A CHANGE OF EVEN ·2 VOLTS WILL CREATE LACK OF WIDTH OR HEIGHT. SO IMAGINE THE EFFECT OF ·5 VOLTS. (THIS CHANGE IN VOLTAGE WOULD RESULT FROM THE VARYING BRIGHTNESS LEVELS & THIS WOULD ALTER THE CURRENT REQUIREMENTS).

A CURRENT LIMITING CIRCUIT CAN BE PLACED ON THE INPUT SIDE OF THE PASS TRANSISTOR. WHERE IT WILL HAVE THE LEAST EFFECT ON THE OUTPUT VOLTAGE. THE FOLLOWING CIRCUIT SHOWS THIS:



IN THIS CIRCUIT Q1 IS THE SERIES PASS TRANSISTOR. Q2 IS THE SENSING AMPLIFIER AND Q3 IS THE OVERLOAD DETECTOR. WE HAVE SEEN HOW Q2 OPERATES. IF IT WERE REMOVED AND THE ZENER DIODE CONNECTED TO THE BASE OF Q1, THE BLEED CURRENT WOULD NEED TO BE AT LEAST 10 TIMES GREATER. (SEE THE PREVIOUS REASONING FOR THIS) Q2 SERVES TO AMPLIFY THE VOLTAGE IT DETECTS ON ITS BASE TO SUPPLY Q1 WITH THE REQUIRED CORRENT AS Q1 WILL NEED AT LEAST 20mA BASE CURRENT & POSSIBLY MORE LIKE 50mA. THIS ALLOWS THE ZENER DIODE TO HAVE A LOWER BLEED CURRENT.

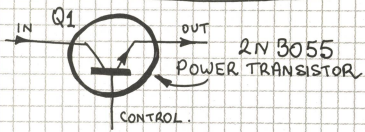
ACTUALLY THE CURRENT

UNDER NORMAL CONDITIONS Q3 IS NOT TURNED ON AND PLAYS NO PART IN THE OPERATION OF THE CIRCUIT.

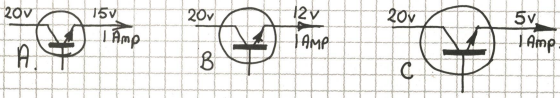
THE 4 1Ω RESISTORS IN PARALLEL COMBINE TO FORM A ·25Ω RESISTOR, AND WHEN THE CURRENT APPROACHES 2 AMPS A VOLTAGE OF ·25 x 2 = ·5 VOLT WILL DEVELOP ACROSS THE COMBINATION. THIS BEGINS TO TURN ON Q3 AND IF THE CURRENT INCREASES FURTHER Q3 WILL TURN ON FULLY TO SHORT-OUT MOST OF THE ZENER DIODE VOLTAGE. THE BASE OF Q2 WILL THEN SEE A VOLTAGE AS LOW AS 3 – 4 VOLTS. THE EMITTER OF Q2 WILL FOLLOW THIS FALL WITH A VOLTAGE ON ITS EMITTER OF 2·4 – 3·4 VOLTS. THE OUTPUT OF Q1 WILL REDUCE TO 1·8 – 2·6 VOLTS.

IF THIS LOW VOLTAGE IS CAPABLE OF SUPPLYING THE 2 AMPS AS IN A SHORT-CIRCUIT CONDITION, THE CIRCUIT WILL REMAIN IN THIS SHUT-DOWN MODE. THIS MAY BE PROTECTING THE EQUIPMENT BEING SUPPLIED BUT THE POWER SUPPLY ITSELF WILL BE SUFFERING GREATLY AS WE SHALL SEE IN THE NEXT SECTION.

POWER-LOSS IN A SERIES REGULATOR



THE SERIES PASS TRANSISTOR Q1 CAN BE THOUGHT OF AS A RESISTOR WHEN CONSIDERING THE POWER LOSS IT MUST DISSIPATE. TAKE THESE THREE CASES:



IN THESE 3 EXAMPLES A B & C, THE OUTPUTS ARE 15v 12v & 5v @ 1 AMP WHICH TRANSISTOR WILL HAVE THE GREATEST HEAT LOSS? IN OTHER WORDS, WHICH TRANSISTOR WILL HEAT UP THE MOST? YES! C! THE REASON IS SIMPLE. THE TRANSISTOR IS DROPPING THE MOST VOLTAGE (OF THE 3 CASES). THE TRANSISTOR IS EFFECTIVELY A DROPPER RESISTOR AND MUST DISSIPATE HEAT ACCORDING TO OHMS LAW.

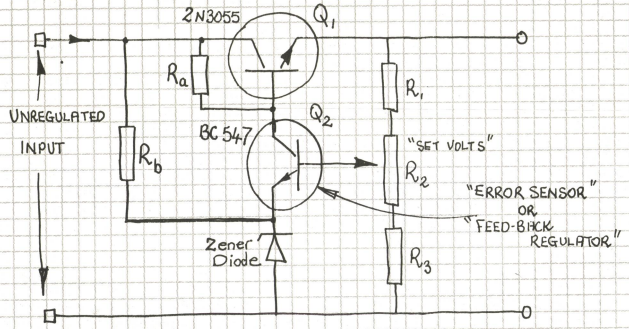
IN CASE A THE VOLTAGE ACROSS THE TRANSISTOR IS 20 – 15 = 5 VOLTS AND THE WATTAGE BEING DISSIPATED IS 5 x 1 = 5 WATTS.
IN CASE C THE WATTAGE IS 15 WATTS – A CONSIDERABLE INCREASE.

IF THE OUTPUT OF A POWER SUPPLY IS SHORT-CIRCUITED THE WHOLE INPUT VOLTAGE WILL BE DROPPED ACROSS THE POWER TRANSISTOR AND WILL RESULT IN ENORMOUS HEATING PROBLEMS. FOR THIS REASON THE REGULATOR TRANSISTOR MUST BE EFFECTIVELY HEAT SINKED.

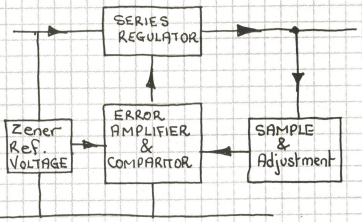
THE OP-AMP IN POWER SUPPLIES

FIRSTLY A LOOK AT THE TRANSISTOR VERSION OF AN "ERROR SENSOR" THEN WE WILL SEE HOW AN OPERATIONAL AMPLIFIER FITS IN.

THE CIRCUIT SHOWS A SERIES PASS TRANSISTOR 2N3055 AND AN "ERROR SENSOR" TRANSISTOR BC547 (WIRED TO FORM A FEED-BACK REGULATOR.)



THE WAY IN WHICH THE CIRCUIT WORKS CAN BEST BE EXPLAINED WITH THE AID OF A BLOCK DIAGRAM.



THE SERIES PASS TRANSISTOR CAN BE CONSIDERED AS A VARIABLE RESISTANCE, SO THAT AT ANY STAGE IT HAS AN "EFFECTIVE RESISTANCE" & A VOLTAGE IS DROPPED ACROSS THE COLLECTOR - EMITTER LEADS (C-E JUNCTION)

IF THE CURRENT DEMAND (THE CURRENT THROUGH THE LOAD) INCREASES, THE VOLTAGE ACROSS THE PASS TRANSISTOR (C-E LEADS) INCREASES & THE OUTPUT VOLTAGE TO THE LOAD WOULD DECREASE.

THE RESISTORS R_1, R_2 & R_3 FORM A VOLTAGE DIVIDER ACROSS THE OUTPUT, & THE CENTRE ARM OF THE VARIABLE RESISTOR R_2 WILL DETECT THIS DROP IN VOLTAGE. [NOT THE FULL VOLTAGE DROP BUT STILL A VOLTAGE DROP].

INITIALLY Q_2 IS ACTING AS A COMPARITOR, COMPARING THE ACCURATE ZENER REFERENCE VOLTAGE WITH THE "SET VOLTS," TO CONTROL THE VOLTAGE ON THE BASE OF Q_1.

WHEN THE POWER IS APPLIED, Q_1 IS FULLY TURNED ON VIA R_a & THE OUTPUT VOLTAGE RISES UNTIL Q_2 TURNS ON VIA THE VOLTAGE ON THE SLIDER OF R_2. THE BC547 IS PRODUCING A VOLTAGE DROP BETWEEN COLLECTOR AND EMITTER TERMINALS AND THIS IS ADDED TO THE ZENER VOLTAGE.

THE BASE OF THE 2N3055 "SEES" THIS VOLTAGE AND PRODUCES AN OUTPUT AT THE EMITTER WHICH IS -6v LESS THAN THE BASE VOLTAGE.

THIS OUTPUT VOLTAGE IS PASSED TO THE BC 547 & THE 2N3055 TRANSISTOR MAY ADJUST ITS COLLECTOR VOLTAGE UNTIL A STATE IS PRODUCED WHICH IS STABLE FOR THE SETTING OF R_2.

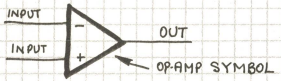
IF THE LOAD-CURRENT INCREASES, THE VOLTAGE ON THE BASE OF Q_2 FALLS SLIGHTLY & Q_2 TURNS OFF SLIGHTLY SO THAT THE VOLTAGE ON THE BASE OF Q_1 RISES VIA R_a. Q_1 TURNS ON HARDER TO INCREASE THE OUTPUT VOLTAGE.

THE "ERROR AMPLIFIER" Q_2 IS WELL NAMED. IT DETECTS ANY DIFFERENCE BETWEEN THE ZENER VOLTAGE & THE REFERENCE VOLTAGE. IF THE REFERENCE VOLTAGE (KNOWN AS THE ERROR SIGNAL) CHANGES, THE TRANSISTOR AMPLIFIES THIS SIGNAL AND FEEDS IT BACK TO THE BASE OF THE SERIES PASS TRANSISTOR TO ADJUST ITS EFFECTIVE RESISTANCE".

THE SAME ERROR DETECTION CAN BE PRODUCED BY AN OP-AMP, but FIRSTLY LET'S LOOK AT:

HOW THE OP-AMP WORKS

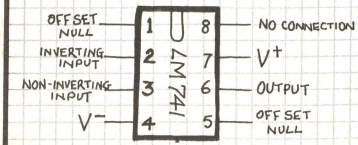
THE 3 SIGNAL LINES ARE:

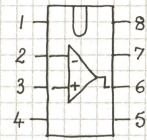


OP-AMP DIAGRAM.

THE OP-AMP WE WILL BE USING IS A 741 OP-AMP.

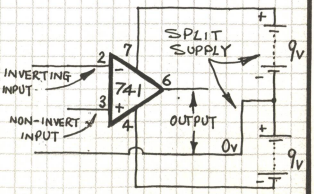
WE WILL BE USING THE 8 PIN VERSION:



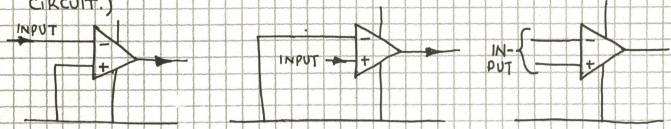


THE LM741 OP-AMP

THE 741 OP-AMP IS DESIGNED TO OPERATE FROM A SPLIT POWER SUPPLY:



THE OP-AMP CAN BE DESIGNED TO OPERATE AS AN INVERTING AMPLIFIER (+ CONNECTED TO 0v) NON INVERTING AMPLIFIER (− TO 0v) OR AS A DIFFERENTIAL AMPLIFIER − (AS PER OUR NEXT POWER SUPPLY CIRCUIT.)

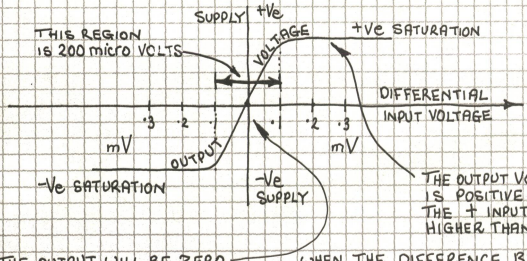


741 AS AN INVERTING AMPLIFIER

741 AS A NON-INVERTING AMPLIFIER.

741 AS A DIFFERENTIAL AMPLIFIER

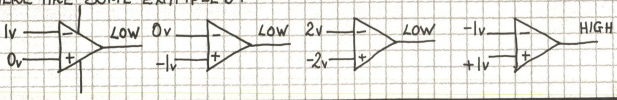
THE OP-AMP IS DIRECTLY COUPLED THROUGHOUT AND HAS A VERY HIGH GAIN. (TYPICALLY 100,000) AND THIS MAKES THEM VERY SENSITIVE & IDEAL AS "ERROR SENSORS" BECAUSE THE SENSING RANGE FOR THE OP-AMP IS ONLY ABOUT 100 MICRO-VOLTS. AS SHOWN IN THE GRAPH BELOW:
THE FOLLOWING GRAPH SHOWS HOW THE OUTPUT VOLTAGE CHANGES ACCORDING TO THE VOLTAGE ON THE TWO INPUTS.



THE OUTPUT WILL BE ZERO WHEN THE DIFFERENCE BETWEEN THE TWO INPUT VOLTAGES IS ZERO. AS THE VOLTAGE ON THE + INPUT INCREASES THE OUTPUT GOES HIGH. IF THE − INPUT IS TAKEN TO THE SAME POSITIVE VALUE, THE OUTPUT WILL FALL TO ZERO

IF THE − INPUT IS TAKEN NEGATIVE, THE OUTPUT WILL GO MINUS. IF THE + INPUT IS TAKEN TO THE SAME NEGATIVE VALUE, THE OUTPUT WILL BECOME ZERO. (VOLTS)

HERE ARE SOME EXAMPLES:



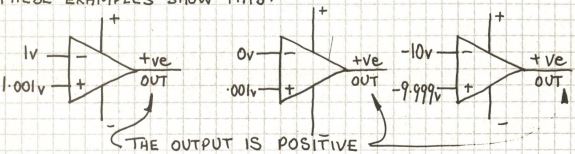
DID YOU FULLY UNDERSTAND THE ANSWERS TO THE 4 EXAMPLES ON THE PREVIOUS PAGE?
IF NOT, WE WILL EXPLAIN HOW THE OUTPUT CHANGES ACCORDING TO THE VOLTAGE ON THE INPUTS.
THE 741 OP-AMP USES A SPLIT POWER SUPPLY ie. +9V ON PIN 7 & −9V ON PIN 4. WITH THIS TYPE OF SUPPLY, THE OUTPUT WILL GO HIGH: TO 9V & LOW: TO −9V. IT WILL SWING 18V.
THIS 18V SWING OCCURS WHEN THE INPUT VOLTAGE CHANGES 200μV. IN THIS 200μV REGION THE OP-AMP IS WORKING IN ITS LINEAR RANGE.

POWER SUPPLY CIRCUITS USE THE OP-AMP IN ITS LINEAR RANGE & THUS A VERY SMALL CHANGE ON THE INPUT WILL PRODUCE A LARGE CHANGE ON THE OUTPUT. OF THE OP-AMP (NOT THE POWER SUPPLY)

BUT THE OUTPUT CAN BE POSITIVE OR NEGATIVE, ACCORDING TO THE VOLTAGE ON THE INPUTS.
YOU MUST BE ABLE TO DETERMINE THE SIGN OF THE OUTPUT WHEN THE 741 IS USED AS A COMPARITOR. [IN THE LINEAR RANGE]

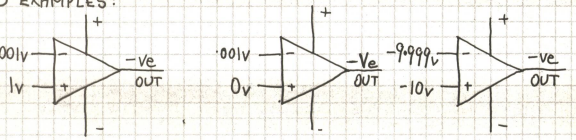
IN THE LINEAR REGION: IF THE (+) INPUT IS HELD WITHIN 200μV ABOVE THE (−) INPUT, THE OUTPUT WILL BE A POSITIVE VOLTAGE WHICH IS PROPORTIONAL TO THE DIFFERENCE BETWEEN THE TWO INPUTS.

THESE EXAMPLES SHOW THIS:



IF THE (−) INPUT IS HELD WITHIN 200μV ABOVE THE (+) INPUT, THE OUTPUT WILL BE A NEGATIVE LINEAR VOLTAGE PROPORTIONAL TO THE DIFFERENCE BETWEEN THE INPUT LINES.

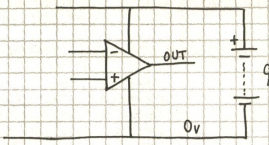
3 EXAMPLES:



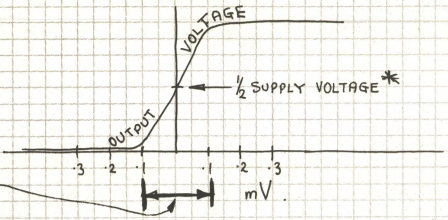
SUMMARY

IF THE NON-INVERTING INPUT (+) HAS THE HIGHER VOLTAGE: THE OUTPUT WILL BE POSITIVE.
IF THE INVERTING INPUT (−) HAS THE HIGHER VOLTAGE: THE OUTPUT WILL BE NEGATIVE.

THE OP-AMP WILL ALSO OPERATE FROM A SINGLE POWER SUPPLY:



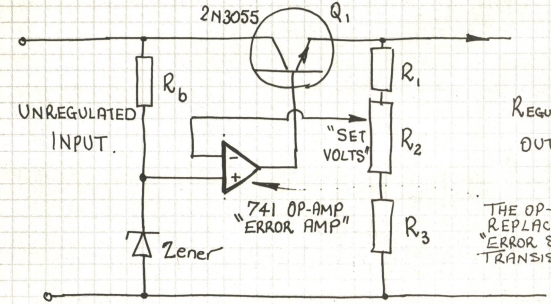
· THE OUTPUT WAVEFORM:



* AT ZERO DIFFERENCE BETWEEN INPUTS THE OUTPUT WILL BE ½ RAIL VOLTAGE.

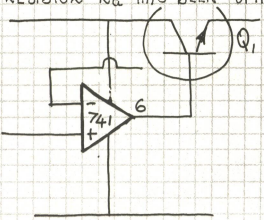
· THE INPUT VOLTAGE DIFFERENTIAL OPERATING RANGE IS ABOUT ·2 MILLIVOLTS FOR FULL OUTPUT SWING. (= 200 MICRO VOLTS)

AN OP-AMP WILL REPLACE THE ERROR SENSING TRANSISTOR



TWO POINTS NEED EXPLAINING:

(i) TWO POWER RAILS FOR THE OP-AMP ARE NOT DRAWN & IT MAY BE DIFFICULT TO SEE HOW THE OP-AMP FUNCTIONS.
(ii) RESISTOR R_a HAS BEEN OMITTED. – WHY?



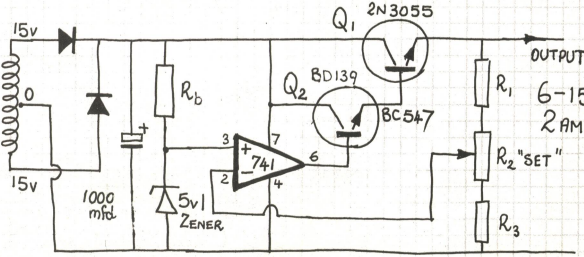
WHEN THE POWER RAILS FOR THE OP-AMP ARE INCLUDED – IT IS EASY TO SEE WHERE THE BASE OF THE 2N3055 GETS ITS "TURN-ON" VOLTAGE FROM — THROUGH THE OP-AMP POWER RAIL & PIN 6.

& THIS MEANS R_a IS NOT REQUIRED.

WHEN THE CIRCUIT IS SWITCHED ON, THE VOLTAGE ENTERING THE NON-INVERTING INPUT (+) TURNS THE OP-AMP ON FULLY TO DRIVE THE 2N3055 INTO FULL CONDUCTION. THE OUTPUT OF THE POWER SUPPLY RISES UNTIL THE FEEDBACK VOLTAGE FROM THE "ADJUST" CONTROL R_2 REDUCES THE TURN-ON VOLTAGE FROM THE OP-AMP & THE OUTPUT VOLTAGE SETTLES TO THE "SET" VOLTAGE.

BUFFERING THE OP-AMP

AN OP-AMP IS CAPABLE OF DRIVING A 2N3055 DIRECTLY. THIS WILL PRODUCE A POWER SUPPLY WITH A LIMITED OUTPUT CURRENT HERE IS WHY:
THE OP-AMP CAN DELIVER ABOUT 25mA. THIS CURRENT WILL DRIVE THE BASE OF THE 2N3055 & IF THE CURRENT GAIN OF A 2N3055 IS 20, THE OUTPUT OF THE POWER SUPPLY WILL BE $25 \times 20 = 500$ mA. TO INCREASE THIS CURRENT WE NEED AN AMPLIFIER AS FOLLOWS:



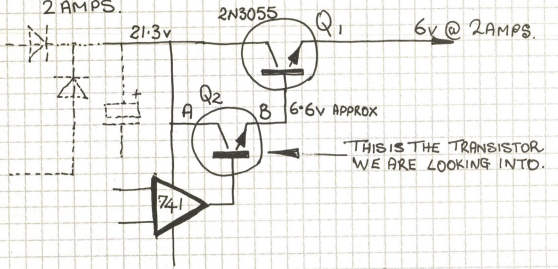
POWER SUPPLY WITH CURRENT AMPLIFYING TRANSISTOR Q_2.

THE DRIVER TRANSISTOR

by G.T. Dicker

THE PREVIOUS PAGE CONTAINED A SLIGHT MISTAKE IN THE POWER SUPPLY CIRCUIT DIAGRAM.
THE BC547 CURRENT AMPLIFYING TRANSISTOR WILL WORK BUT ITS ABILITY TO DISSIPATE THE POWER WILL BE INADEQUATE.
HERE'S WHY:

TAKING THE CASE WHERE THE GREATEST POWER IS BEING DISSIPATED (LOST) IN THE SERIES PASS TRANSISTOR Q_1 (2N3055) THE CURRENT AMPLIFYING TRANSISTOR Q_2 ALSO HAS THE GREATEST LOSS — THIS APPLIES WHEN THE OUTPUT IS 6 VOLTS AND THE CURRENT 2 AMPS.



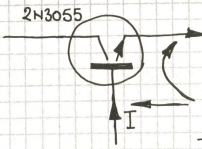
USING A 15v -0- 15v TRANSFORMER & 2 DIODES, THE VOLTAGE-OUT FROM THE DIODES WILL BE:

$= \cdot 71 \times 30$
$= 21 \cdot 3$ VOLTS.

THE VOLTAGE BETWEEN POINTS A&B WILL BE:

$= 21 \cdot 3 - 6 \cdot 6$
$= 14 \cdot 7$ VOLTS.

THE DRIVING CURRENT FOR Q_1 WILL BE:



TO GET 2AMPS TO FLOW THROUGH THE COLLECTOR-EMITTER CIRCUIT WE HAVE TO PROVIDE CURRENT INTO THE BASE CIRCUIT. THE AMOUNT OF BASE CURRENT WILL DEPEND ON THE "GAIN" OF THE TRANSISTOR.

FOR A 2N3055 ITS GAIN IS ABOUT 10-100 THIS MEANS WE NEED ONLY ABOUT 1/10 OR 1/100 OF 2 AMPS INTO THE BASE TO GET 2 AMPS TO FLOW IN THE COLLECTOR CIRCUIT.

. BASE CURRENT:

$$= \frac{2 \text{ AMPS}}{\text{GAIN OF THE TRANSISTOR}}$$

H_{FE} IS THE GAIN & WE WILL CHOOSE A VALUE OF 20.

$$= \frac{2}{20} \text{ AMPS}$$

$$= \frac{1}{10} \text{ AMP} = 100 \text{ mA}.$$

THIS CURRENT MUST BE SUPPLIED BY Q_2.

THE POWER DISSIPATED BY Q_2: [POWER = VOLTS x AMPS]

$$= 14{\cdot}7 \times {\cdot}1 \text{ WATTS}$$

$$= 1{\cdot}47 \text{ WATTS}.$$

CLEARLY THIS IS GREATER THAN THE ABILITY OF A BC547 AS IT CAN ONLY DISSIPATE 500mW. — WITH A HEATSINK IT CAN BE UP-RATED TO ABOUT 1 WATT BUT TO BE ON THE SAFE SIDE IT IS ADVISABLE TO USE A TRANSISTOR SUCH AS BC139 OR TIP 32 AS THESE HAVE A METAL FLANGE WHICH CAN BE BOLTED TO A HEATSINK.

THE MINIMUM POWER DISSIPATED BY Q_2 WILL OCCUR WHEN THE OUTPUT IS 15V. FOR THIS CASE THE LOSSES IN Q_2 WILL BE:

$$= 21{\cdot}3\text{v} - 15{\cdot}6\text{v}$$
$$= 5{\cdot}7\text{v}.$$

POWER DISSIPATED BY Q_2 WILL BE:

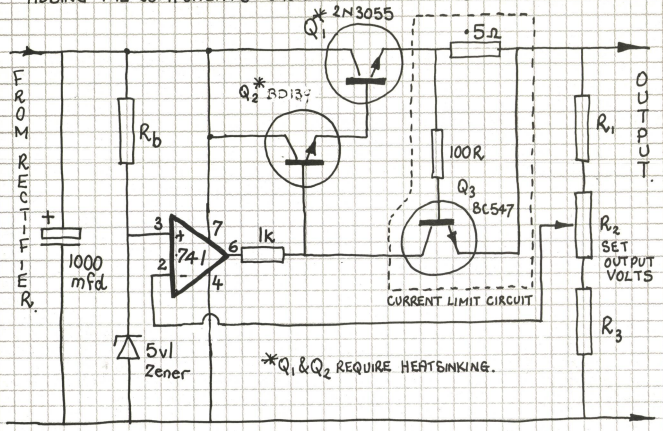
$$= 5{\cdot}7 \times {\cdot}1$$
$$= {\cdot}57 \text{ WATTS}.$$

THIS SHOWS THAT AS THE OUTPUT VOLTAGE IS REDUCED FROM 15V TO 6V, THE POWER LOST IN Q_1 & Q_2 INCREASES.

THIS SEEMS LOGICAL. THE TRANSFORMER & RECTIFIER IS SUPPLYING A CONSTANT AMOUNT OF ENERGY. IF THIS POWER IS NOT BEING USED BY THE LOAD, IT MUST BE LOST IN THE REGULATING NETWORK.

CURRENT LIMITING

THE NEXT STAGE IN POWER SUPPLY DESIGN IS TO LIMIT THE OUTPUT CURRENT DURING SHORT-CIRCUIT CONDITIONS. THIS IS ACHIEVED BY ADDING THE COMPONENTS SHOWN IN THE DOTTED BLOCK:



POWER SUPPLY WITH CURRENT LIMITING.

THE MAXIMUM OUTPUT CURRENT IS DETERMINED BY THE ·5Ω. A 1Ω RESISTOR WILL GIVE A 500mA SUPPLY, ·5Ω GIVES A 1 AMP SUPPLY & ·25Ω GIVES A 2AMP SUPPLY (APPROX.)

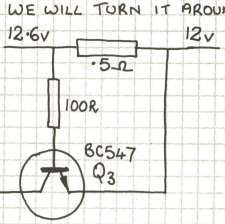
DURING NORMAL OPERATION (UP TO ABOUT 1AMP WITH THE ·5Ω RESISTOR) THE CURRENT LIMITING CIRCUIT DOES NOT COME INTO OPERATION AT ALL. ITS ONLY EFFECT IS THE ·5v DROP ACROSS THE ·5Ω RESISTOR. BUT THIS ·5v DROP IS TAKEN INTO ACCOUNT BY THE SENSING CIRCUIT BECAUSE THE OUTPUT VOLTAGE IS DETECTED AFTER ALL THE DROPS IN VOLTAGE HAVE TAKEN PLACE IN THE REGULATING COMPONENTS.

WHEN THE CURRENT RISES OVER 1 AMP, TO SAY 1·2 AMP, THE VOLTAGE ACROSS THE ·5Ω RESISTOR INCREASES TO ·6v AND IS PASSED TO Q3 WHERE IT APPEARS BETWEEN THE BASE & EMITTER LEADS. THIS VOLTAGE WILL BEGIN TO TURN THE TRANSISTOR ON SO THAT THE VOLTAGE AT THE COLLECTOR WILL BE DRAWN DOWN SLIGHTLY. THIS IS DUE TO Q3 BECOMING EQUIVALENT TO A LOW-VALUE RESISTOR, & THE EMITTER VOLTAGE (WHICH IS EQUAL TO THE OUTPUT VOLTAGE OF THE POWER SUPPLY) WILL BE LOWER THAN THE VOLTAGE ON BASE OF Q2

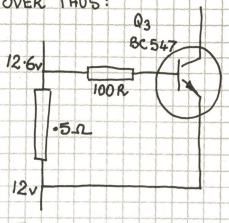
THE 100R RESISTOR IN THE BASE LINE ALLOWS THE CURRENT-LIMIT TRANSISTOR TO OPERATE IN ITS FULL SATURATION MODE WITHOUT BEING OVER-STRESSED WITH AN EXCESS BASE-EMITTER VOLTAGE WHICH MAY OCCUR WHEN HIGH CURRENTS FLOW THROUGH THE ·5Ω RESISTOR.

HOW THE CURRENT-LIMIT TRANSISTOR WORKS

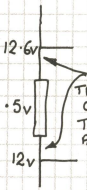
THIS TRANSISTOR CAN BE CONSIDERED AS A COMPLETELY SEPARATE CIRCUIT. TO MAKE IT EASY TO FOLLOW THE OPERATION OF THE CIRCUIT WE WILL TURN IT AROUND & OVER THUS:



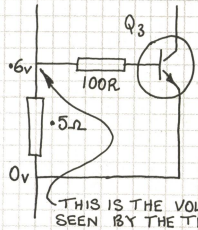
THE CURRENT-LIMIT CIRCUIT EXTRACTED FROM THE PREVIOUS DIAGRAM.



THE SAME CIRCUIT TURNED AROUND TO MAKE IT EASIER TO SEE HOW THE TRANSISTOR IS OPERATING.



AS FAR AS THE TRANSISTOR IS CONCERNED, THE TRANSISTOR "SEES" A VOLTAGE OF ·6V ACROSS THE ·5Ω RESISTOR.



THIS IS THE VOLTAGE AS SEEN BY THE TRANSISTOR.

THE TRANSISTOR "SEES" ·6V ON ITS BASE (WITH RESPECT TO THE EMITTER LEAD) AND THIS IS ALL THAT MATTERS TO THE TRANSISTOR. YOU WILL NOW BE ABLE TO SEE WHY THE TRANSISTOR TURNS ON. THE 100R RESISTOR IS ONLY A BUFFER RESISTOR TO PREVENT EXCESS CURRENT FLOWING THROUGH THE BASE CIRCUIT WHEN THE POWER SUPPLY IS IN SHORT-CIRCUIT CONDITIONS.
THE 100Ω RESISTOR CAN BE INCREASED TO 1K WITHOUT AFFECTING THE OPERATION OF THE CIRCUIT — THAT'S WHAT WE MEAN BY A BUFFER RESISTOR.

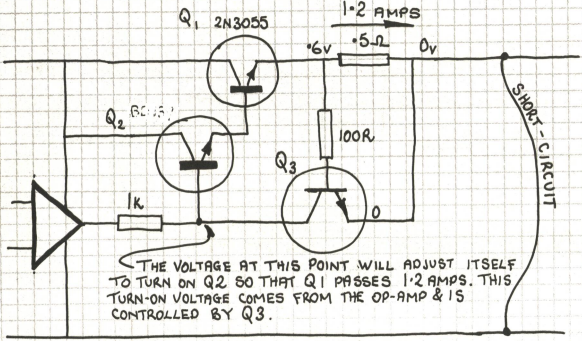
THE OPERATION OF THE OP-AMP

WHEN THE OUTPUT CURRENT INCREASES, THE OUTPUT VOLTAGE WILL DROP SLIGHTLY (DUE TO THE DROP ACROSS THE ·5Ω RESISTOR) AND THE OP-AMP WILL BE TURNED ON HARDER. DURING AN OVERLOAD CONDITION THE OP-AMP WILL BE DRIVING THE BASE OF Q_2 FULLY & TO PREVENT THE OP-AMP BEING DAMAGED WHEN THE OUTPUT IS SHORT-CIRCUITED, WE HAVE ADDED A 1K RESISTOR (TO OUTPUT PIN Nº6)

THE CURRENT-LIMITING CIRCUIT WILL BE ESPECIALLY APPRECIATED WHEN A SHORT-CIRCUIT OCCURS AS IT WILL LIMIT THE CURRENT TO ABOUT 1·2 AMPS. WITHOUT THIS CIRCUIT THE CURRENT WOULD BE CONSIDERABLY GREATER AND MAY BE EVEN 3-4 AMPS DEPENDING ON THE ABILITY OF THE TRANSFORMER TO SUPPLY THE CURRENT.

THE OPERATION OF THE CURRENT LIMITER

WHEN THE OUTPUT IS SHORT-CIRCUITED A CURRENT OF ABOUT 1·2 AMPS WILL BE FLOWING IN THE ·5Ω RESISTOR TO KEEP THE CURRENT-LIMITER TRANSISTOR IN OPERATION.



THE POWER SUPPLY IN SHORT-CIRCUIT CONDITIONS.

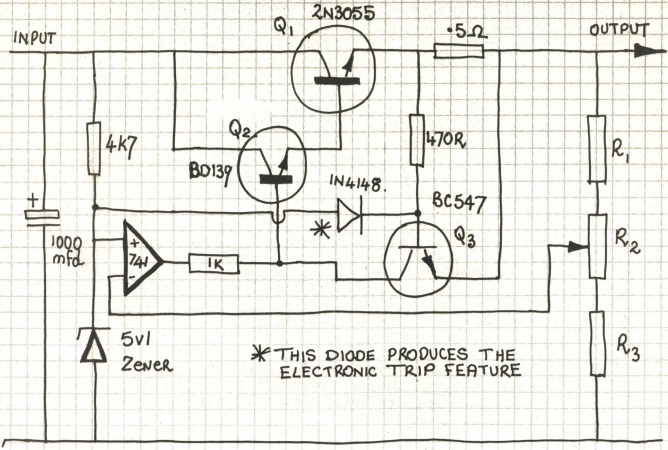
THIS MEANS THE SERIES-PASS TRANSISTOR Q1 WILL BE DISSIPATING A VERY HIGH WATTAGE (WHICH WILL BE EVEN HIGHER THAN ITS NORMAL OPERATING DISSIPATION). FOR THIS REASON AN IMPROVED SHUT-DOWN IS REQUIRED TO LIMIT THE LOSSES IN THE REGULATOR WHEN THE OUTPUT IS SHORT-CIRCUITED.

ELECTRONIC TRIP

FINALLY WE COME TO THE MOST IMPORTANT FEATURE OF ALL.... AN ELECTRONIC TRIP WHICH TURNS THE POWER SUPPLY OFF WHEN EXCESS CURRENT IS DRAWN OR A SHORT-CIRCUIT OCCURS. THE ADVANTAGES OF A SHUT-DOWN SUPPLY ARE:

1. REDUCES THE HEAT BUILD-UP IN THE POWER TRANSISTOR.
2. REDUCES THE OVERLOADING ON THE TRANSFORMER.
3. REDUCES THE RISK OF BURN OUT AND/OR FIRE IN THE POWER SUPPLY.

TO ACHIEVE THIS SHUT-DOWN CONDITION ONLY 1 COMPONENT IS NEEDED. A DIODE IS PLACED BETWEEN THE REFERENCE ZENER & THE BASE OF THE CURRENT LIMITING TRANSISTOR.



1AMP POWER SUPPLY WITH ELECTRONIC TRIP

THE ELECTRONIC TRIP WILL ONLY COME INTO OPERATION WHEN THE VOLTAGE ON THE BASE OF Q3 IS BELOW THE ZENER REFERENCE VOLTAGE. WHEN THIS OCCURS THE TURN-ON VOLTAGE FOR THE LIMITING TRANSISTOR DOES NOT COME FROM FROM THE VOLTAGE DROP ACROSS THE •5Ω RESISTOR BUT FROM THE "BLEED CURRENT" KEEPING THE ZENER IN BREAKDOWN. IN SHUT-DOWN THE OUTPUT CURRENT FALLS TO A FEW mA & WILL START-UP WHEN THE SHORT IS REMOVED.

THE VOLTAGE REGULATOR

THE SECTION WE HAVE COVERED IS CALLED THE "FRONT-END". IT INCLUDES THE TRANSFORMER, BRIDGE & SMOOTHING ELECTROLYTIC. THIS SIMPLE ARRANGEMENT MAY BE GOOD ENOUGH TO RUN A MODEL TRAIN BUT CERTAINLY NOT GOOD ENOUGH FOR ANYTHING ELECTRONIC.

WHAT IS NEEDED IS AN ADDITIONAL STAGE OF SMOOTHING — AND THIS IS ADDED IN THE FORM OF A VOLTAGE REGULATOR CHIP. THIS SECTION COVERS THE COMPLETE OPERATION OF ONE PARTICULAR TYPE. — THE 7805:

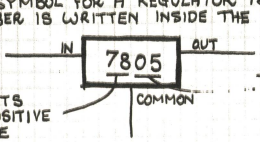
INSIDE THESE VOLTAGE REGULATOR CHIPS IS A COMPLETE & COMPLEX CIRCUIT. IT CONTAINS A VOLTAGE REFERENCE, A CURRENT LIMIT DETECTOR, THERMAL OVERLOAD & CURRENT-PASS TRANSISTOR. ALL THIS ELECTRONIC INGENUITY COSTS ABOUT ONE DOLLAR! AND AT THIS PRICE, THE REGULATOR IS A VERY CHEAP INVESTMENT.

BY USING A VOLTAGE-REGULATOR CHIP A POWER SUPPLY CAN BE REDUCED TO 4 COMPONENTS. ① A POWER TRANSFORMER ② A BRIDGE RECTIFIER ③ A HIGH-VALUE SMOOTHING ELECTROLYTIC AND ④ A VOLTAGE REGULATOR CHIP. THIS TURNS A POWER SUPPLY INTO A SIMPLE PROJECT SO THAT EVEN A BEGINNER CAN BUILD A 1AMP FULLY REGULATED POWER SUPPLY TO POWER HIS PROJECTS.

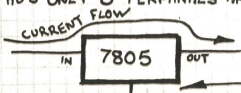
BASICALLY A VOLTAGE REGULATOR IS A SILICON CHIP MOUNTED ON A PIECE OF METAL & ENCLOSED IN AN EPOXY PACKAGE. IT IS NOT NECESSARY TO KNOW HOW IT WORKS INTERNALLY BUT IT IS IMPORTANT TO CORRECTLY CONNECT IT INTO A CIRCUIT & PREVENT IT BEING OVERLOADED WITH CURRENT OR VOLTAGE

THE MOST COMMON REGULATOR IS A 7805. THIS IS A 5 VOLT REGULATOR WHICH MEANS ITS OUTPUT IS 5 VOLTS. THE OTHER IMPORTANT CHARACTERISTIC OF A REGULATOR IS THE CURRENT RATING (1·5 AMP IN THIS CASE).

THE CIRCUIT SYMBOL FOR A REGULATOR IS A RECTANGULAR BOX THE TYPE-NUMBER IS WRITTEN INSIDE THE BOX.

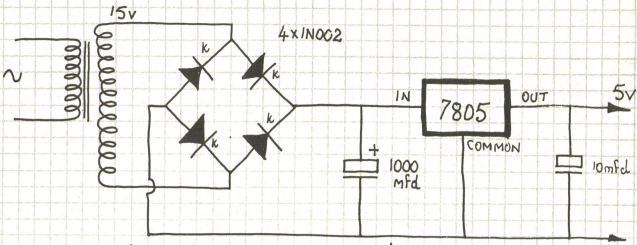


THE REGULATOR OBTAINS THE CURRENT FOR THE CIRCUIT INSIDE THE REGULATOR FROM THE **IN** TERMINAL (AND THE **COMMON** TERMINAL) AND THUS ONLY 3 TERMINALS ARE NEEDED.



THIS IS THE DIRECTION OF THE CURRENT FLOW. ALMOST NO CURRENT FLOWS IN THE COMMON LEAD ONLY JUST ENOUGH TO OPERATE THE 7805.

A FULLY-REGULATED POWER SUPPLY:



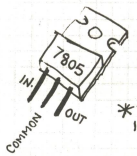
GOOD SMOOTHING IN THIS SECTION MAKES IT EASIER FOR THE REGULATOR TO GIVE A RIPPLE-FREE OUTPUT.

78xx = 7805, 7812 7815 ETC...

THE "78xx" SERIES IS A RANGE OF POSITIVE REGULATORS HAVING A FIXED OUTPUT VOLTAGE ACCORDING TO THEIR CODE NUMBER. TYPE 7805 HAS A 5v OUTPUT, 7812 HAS 12v OUTPUT & 7815 HAS 15v OUTPUT.

[TO OBTAIN A NEGATIVE POWER SUPPLY, WE USE THE "79" SERIES WITH A SIMILAR VOLTAGE RANGE. THIS WILL BE EXPLAINED IN A LATER COURSE.]

THE INPUT VOLTAGE TO A REGULATOR NEEDS TO BE AT LEAST 3v ABOVE THE OUTPUT VOLTAGE. RIPPLE* SHOULD BE KEPT BELOW 1v P-P ON FULL LOAD. WITH THESE CONDITIONS MET, THE REGULATOR WILL SUPPLY 5 VOLTS @ 1 AMP WITH ONLY 1 MILLIVOLT RIPPLE.



*THIS MEANS INPUT RIPPLE.

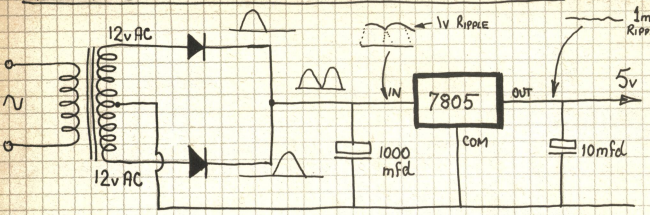
THIS REPRESENTS SMOOTHING OF $\frac{1}{1,000}$ THS OF THE INPUT RIPPLE AND WOULD REQUIRE OVER 100,000 MFD TO PERFORM THE SAME TASK.

THIS ELECTRONIC SMOOTHING FAR OUT-PERFORMS CAPACITOR SMOOTHING FOR COST, SIZE & EFFICIENCY. THE REGULATOR ALSO PROVIDES US WITH THERMAL SHUT-DOWN & OVER-LOAD PROTECTION.

WE SHOULD ALWAYS KEEP THE CURRENT DEMAND BELOW THE MAXIMUM RATING OF THE REGULATOR AS ITS SHUT-DOWN ABILITY LEAVES A LOT TO BE DESIRED. IF THE OUTPUT OF THE POWER-SUPPLY IS SHORTED THE REGULATOR BECOMES EXTREMELY HOT AND WITHOUT ADEQUATE HEATSINKING, WILL BE DAMAGED.

TO KEEP 3-TERMINAL REGULATORS OPERATING IN THEIR REGULATION — MODE, WE MUST PROVIDE GOOD SMOOTHING BEFORE THE INPUT PIN. THIS MEANS THE TRANSFORMER SHOULD NOT BE OVER-LOADED OR OPERATED TOO NEAR ITS MAXIMUM RATING.

REGULATED POWER SUPPLY USING A C-T TRANSFORMER

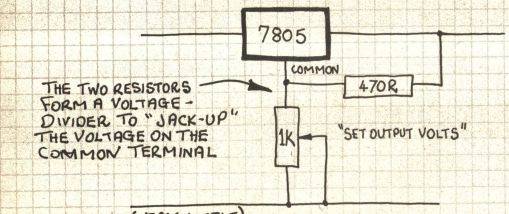


A 3-TERMINAL REGULATOR CAN BE FITTED TO A CENTRE-TAPPED RECTIFIER CIRCUIT WITH PERFECT RESULTS. THE TOP DIODE SUPPLIES THE CURRENT (AND OF COURSE THE VOLTAGE) DURING THE FIRST HALF CYCLE & THE LOWER DIODE PROVIDES THE ENERGY FOR THE SECOND HALF CYCLE. IN THIS CIRCUIT, THE OUTPUT VOLTAGE IS FIXED AT 5v, (ACCORDING TO THE VOLTAGE OF THE '7805'). TO SUPPLY 1 AMP @ 5v THE REGULATOR WILL NEED TO BE MOUNTED ON A HEAT-SINK ABOUT THE SIZE OF YOUR HAND & AS THICK AS THE BORDER OF THIS PAGE.

INCREASING THE OUTPUT VOLTAGE

THE "78xx" & "79xx" SERIES ARE FIXED 3 TERMINAL REGULATORS. HOWEVER THEIR OUTPUT VOLTAGE CAN BE INCREASED BY A SIMPLE METHOD.

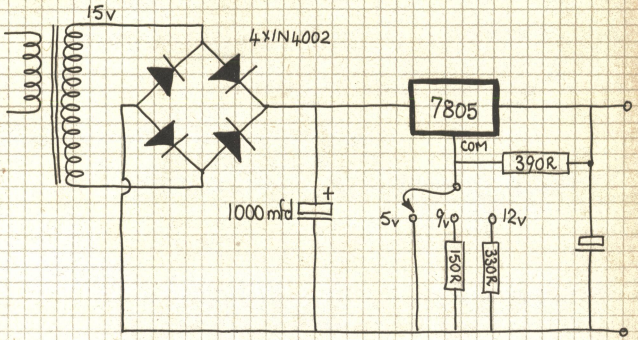
BY INCREASING THE VOLTAGE ON THE COMMON TERMINAL WE CAN INCREASE THE VOLTAGE OUTPUT WITHOUT AFFECTING ANY OTHER CHARACTERISTS. WITH A 7805 THE OUTPUT IS MAINTAINED AT 5v HIGHER THAN THE COMMON TERMINAL. BY PROVIDING A VOLTAGE-DROPPING NETWORK ON THE COMMON TERMINAL WE CAN INCREASE THE OUTPUT TO 9v, 12v OR EVEN HIGHER.



SINCE THERE IS NO CURRENT BEING DRAWN BY THE COMMON TERMINAL, WE MUST PROVIDE A VOLTAGE-DROPPING NETWORK FROM THE OUTPUT-TO-GROUND, TO PRODUCE THE REQUIRED VOLTAGE.

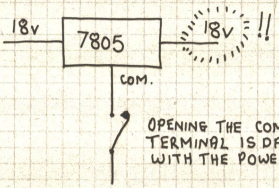
THE "SET OUTPUT VOLTS" CAN BE MADE ADJUSTABLE TO GIVE A COMPLETELY VARIABLE RANGE FROM 5v TO 15 VOLTS.

AN ALTERNATIVE METHOD IS TO PROVIDE A RANGE-CHANGE SWITCH TO SELECT FROM A SET OF FIXED RESISTORS.



5v 9v & 12v SUPPLY

TO OBTAIN AN ACCURATE 9v & 12v RAIL, THE RESISTORS WOULD NEED TO BE TRIMMED BY ADDING OTHER VALUES ACROSS THEM. THE CHANGE-SWITCH SHOULD ONLY BE ADJUSTED WHEN THE POWER IS OFF TO AVOID CREATING AN OPEN CIRCUIT ON THE COMMON TERMINAL WHICH WOULD PRODUCE ABOUT 18v ON THE OUTPUT.

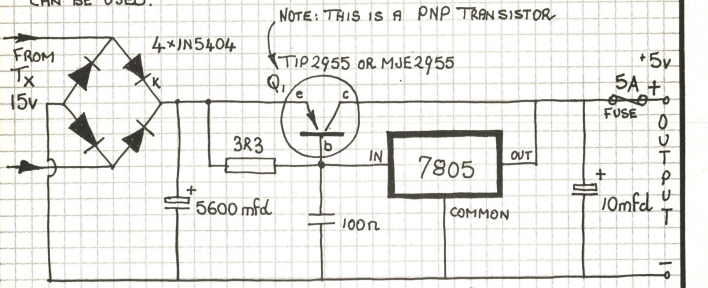


THIS IS THE ULTIMATE IN MINIATURE REGULATED POWER SUPPLIES & CAN BE CONSTRUCTED ON A PC BOARD IN LESS THAN 10 cm^2. THE "LOGIC DESIGNER" SHOWS THIS QUITE CLEARLY.

(SEE LOGIC DESIGNER by COLIN MITCHELL) — BOOK 2 IN A SERIES OF 5 BOOKS.

INCREASING THE CURRENT

THE 7805 IS LIMITED TO ABOUT 1·5 AMPS. WE CAN DESIGN A CIRCUIT TO SUPPLY A HIGHER CURRENT (2 – 5 AMPS). A CURRENT OF 2 OR MORE AMPS IS OFTEN NEEDED FOR CB RADIOS, COMPUTERS & CONTROL EQUIPMENT. A CURRENT BOOSTING CIRCUIT DESIGNED AROUND A 7805 CAN BE USED.



A FIXED 5 VOLT POWER SUPPLY @ 4 AMP.

THIS CIRCUIT USES A TIP 2955 OR MJE 2955. IT IS A 100v PNP TRANSISTOR CAPABLE OF HANDLING 4–5 AMPS.
BY USING A TRANSISTOR AS A SERIES-PASS DEVICE WE CAN DESIGN THE CIRCUIT SO THAT MOST OF THE CURRENT FLOWS THROUGH THE TRANSISTOR AND VERY LITTLE THROUGH THE REGULATOR. THIS MEANS THE REGULATOR REQUIRES VERY LITTLE HEATSINKING BUT IT ALSO INTRODUCES THE FACT THAT CURRENT LIMITING IS NOT AVAILABLE AND A FUSE WILL BE NEEDED IN THE OUTPUT LINE.

HOW THE CIRCUIT WORKS

THE BRIDGE RECTIFIER CONSISTS OF A SET OF 4-AMP DIODES CONNECTED TO A TRANSFORMER CAPABLE OF SUPPLYING ABOUT 5 AMPS. THE OUTPUT VOLTAGE FROM THE TRANSFORMER SHOULD BE ABOUT 10–12v. THE 5600 mfd ELECTROLYTIC SMOOTHES THE DC VOLTAGE TO ABOUT 2v RIPPLE ON FULL LOAD.

THE SECRET OF THE CURRENT-SHARING BETWEEN THE TRANSISTOR AND THE REGULATOR LIES IN THE VALUE OF THE BASE-EMITTER RESISTOR. BY USING A 3R3 RESISTANCE. THE MAXIMUM CURRENT THROUGH THE REGULATOR IS ABOUT 200mA.

WHEN A LOAD IS APPLIED TO THE OUTPUT, CURRENT IS DRAWN. INITALLY (MEANING THE FIRST 200mA OF ANY FLOW) THIS CURRENT IS SUPPLIED BY THE REGULATOR AS THE TRANSISTOR IS FULLY TURNED OFF DUE TO THE 3R3 RESISTOR HAVING NO VOLTAGE ACROSS IT.

AS THE OUTPUT CURRENT INCREASES TO 200mA, THE VOLTAGE DROP ACROSS THE 3R3 BECOMES .66v. THIS VOLTAGE BEGINS TO TURN THE TRANSISTOR ON. AS MORE CURRENT IS REQUIRED BY THE OUTPUT, THE OUTPUT VOLTAGE FALLS VERY SLIGHTLY DUE TO THE TRANSISTOR BEING ONLY PARTLY TURNED ON. THE 7805 SENSES THIS DROP AND DRAWS SLIGHTLY MORE CURRENT THROUGH THE **IN** TERMINAL. THIS EFFECTIVELY TURNS THE TRANSISTOR ON HARDER.

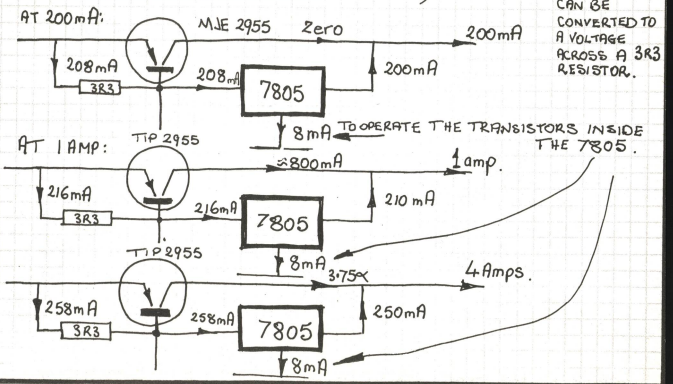
THE 7805 "THINKS" IT HAS PROVIDED THE ADDITIONAL CURRENT BUT, IN FACT, THE TRANSISTOR HAS PROVIDED IT. THIS EFFECT WILL CONTINUE INDEFINITELY. THE ONLY LIMITATION IS THE TRANSISTOR, BRIDGE RECTIFIER DIODES AND THE CURRENT RATING OF THE TRANSFORMER.

THE 7805 WILL NOT SHUT-DOWN AS THE CURRENT RISES BECAUSE ITS MAXIMUM SHARE OF THE CURRENT IS ONLY 200mA. THIS MEANS A 5 AMP FUSE WILL BE NEEDED IN THE OUTPUT LINE TO PREVENT THE TRANSISTOR BEING DESTROYED.

THE FIRST 200mA OF THE LOAD CURRENT IS SUPPLIED BY THE REGULATOR. FURTHER INCREASES IN CURRENT ARE MAINLY SUPPLIED BY THE TRANSISTOR HOWEVER A SLIGHT INCREASE IN THE CURRENT SUPPLIED BY THE REGULATOR IS NEEDED TO TURN THE TRANSISTOR ON HARDER.

THE INCREASE IN REGULATOR CURRENT WOULD BE IN THE ORDER OF *50 MILLIAMPS WHILE THE TRANSISTOR CURRENT INCREASE IS 4 AMPS. THIS INDICATES THE NARROW OPERATING VOLTAGE REQUIRED BY THE TRANSISTOR TO CHANGE IT FROM NON-OPERATING TO FULLY OPERATIONAL. — IN OTHER WORDS, FROM CUT-OFF TO SATURATION.

HOW THE CURRENT IS SHARED (APPROX.)

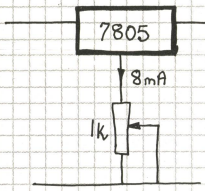


*THE 50mA CAN BE CONVERTED TO A VOLTAGE ACROSS A 3R3 RESISTOR.

VARIABLE VOLTAGE 4-AMP POWER SUPPLY

WE HAVE SEEN THE METHOD FOR INCREASING THE VOLTAGE OF A 5V REGULATOR. THIS CAN ALSO BE ACHIEVED WITH A 12V OR 15V TYPE HOWEVER ITS DESIGNATED OUTPUT VOLTAGE IS GENERALLY THE LOWEST VOLTAGE WHICH CAN BE OBTAINED (VIA A SIMPLE CIRCUIT) AND THUS A 5V TYPE IS THE BEST CHOICE.

3 METHODS OF VARYING THE OUTPUT VOLTAGE.



INCREASING THE OUTPUT TO 15V VOLTAGE

A RESISTOR IN THE "COMMON" LINE WILL INCREASE THE OUTPUT DUE TO THE SMALL CURRENT FLOWING (ABOUT 8-10mA) WHICH IS THE CURRENT CONSUMED BY THE 7805 CIRCUITRY.

THE INCREASED VOLTAGE FROM THIS CIRCUIT CAN BE OBTAINED FROM THE FOLLOWING FORMULA.

$$I = \frac{E}{R}$$

$$\therefore E = IR$$

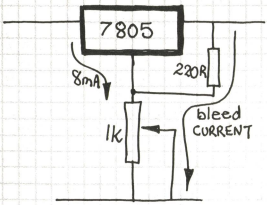
$= \cdot 008 \times 1000$

$= 8$ VOLTS.

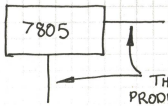
I = CURRENT IN COMMON LINE
E = VOLTAGE RISE
R = RESISTANCE OF POT.

HOWEVER THIS IS NOT A VERY RELIABLE OR STABLE CIRCUIT. AS THE OUTPUT WILL VARY ACCORDING TO THE CURRENT DRAWN BY THE REGULATOR CIRCUITRY.

A MORE RELIABLE ARRANGEMENT IS TO "SWAMP" THE 8mA WITH A BLEED CURRENT OBTAINED FROM THE REGULATOR OUTPUT.



MAX VOLTAGE RISE:



THE REGULATOR PRODUCES A CONSTANT 5V ACROSS THESE TERMINALS.

THEREFORE THE CURRENT IN THE 220R RESISTOR CAN BE OBTAINED FROM.

$$I = \frac{E}{R} = \frac{5}{220} = \cdot 0227$$

$= 22 \cdot 7$ mA.

CURRENT IN COMMON LINE = 8mA + 22·7 mA

≐ 30mA.

VOLTAGE DROP ACROSS 1k POT = I × R

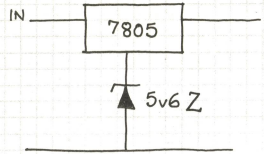
= ·030 × 1000

= 30V.

Maximum VOLTAGE RISE = 5 + 30

= 35 VOLT.

THE THIRD METHOD IS TO ADD A ZENER DIODE IN THE COMMON LINE. THIS WILL HAVE THE EFFECT OF INCREASING THE OUTPUT TO THE SUM OF THE REGULATOR VOLTAGE PLUS THE ZENER VOLTAGE.

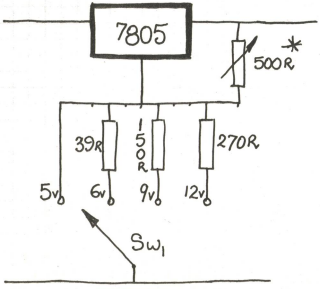


IN THIS CASE THE OUTPUT VOLTAGE WILL BE

= 5 + 5·6

= 10·6v.

AN ACCURATE SET OF OUTPUT VOLTAGES CAN BE OBTAINED BY USING A SET OF FIXED RESISTORS IN PLACE OF THE POT AND SELECTING EACH RESISTOR WITH A JUMPER LEAD OR ROTARY SWITCH.



4 PRE-SET OUTPUT VOLTAGES.

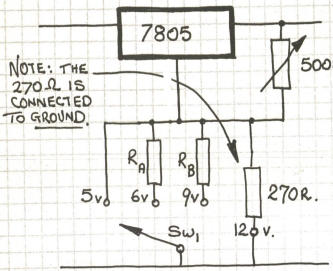
ONE NOTE OF CAUTION WITH THIS TYPE OF ARRANGEMENT. THE SWITCH MUST NOT BE CHANGED WHEN THE POWER IS ON. IF THIS OCCURS THE OUTPUT WILL MOMENTARILY RISE TO THE FULL INPUT VOLTAGE WHEN THE COMMON LINE GOES "OPEN". — THIS WILL DAMAGE THE PROJECT YOU ARE POWERING.

TURN

* DO NOT REDUCE THE 500R POT TO LESS THAN 250R AS IT WILL BURN OUT AND/OR DAMAGE THE PRE-SET RESISTORS.

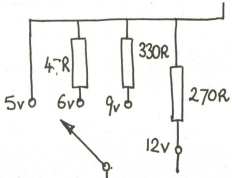
PREVENTING OVER-VOLTAGE

THE OUT-PUT VOLTAGE CAN BE SET TO A MAXIMUM OF 12V BY USING THIS CIRCUIT:



OUTPUT IS 12V MAXIMUM.

THE 270R RESISTOR IN THE 12V RANGE IS PERMANENTLY CONNECTED "IN-CIRCUIT". THIS MEANS THE COMMON LINE IS NEVER ALLOWED TO "FLOAT" AND THUS THE OUTPUT WILL NEVER RISE ABOVE 12V. THE RANGE-CHANGE SWITCH REDUCES THE VOLTAGE TO 5V. 6V OR 9VOLTS.
TO PREVENT THE OUTPUT FROM DAMAGING THE PROJECT BEING POWERED, THE POWER SUPPLY SHOULD BE SWITCHED OFF BEFORE CHANGING THE VOLTAGE.



IF THE POSSIBILITY OF A EXCESS VOLTAGE WILL DAMAGE THE PROJECT YOU ARE SUPPLYING, THE NEXT CIRCUIT IS RECOMMENDED.

CALCULATING THE VALUE OF R_A

THE VOLTAGE DROP ACROSS THE 500R POT IS ALWAYS 5V. THE CURRENT IS CONSTANT IN THE COMMON LINE FOR ANY OUTPUT VOLTAGE.
IF 270R PRODUCES A VOLTAGE DROP OF 7V WHEN THE SWITCH IS SET TO 12V OUTPUT... THE VOLTAGE ACROSS R_A & THE 270R IN PARALLEL MUST BE 1V.

RESISTANCE IN COMMON LINE TO PRODUCE 1V IS
$1/7$ of $270R = 38.6\Omega$.

VALUE OF R_A:

$$\frac{1}{38.6} = \frac{1}{R_A} + \frac{1}{270.}$$

$$38.6 = \frac{270\,R_A}{R_A + 270}$$

$$38.6R_A + 38.6 \times 270 = 270\,R_A$$

$$38 \times 270 = 232\,R_A.$$

$$\Rightarrow R_A = 44\Omega.$$
USE 47Ω.

VALUE OF R_B:

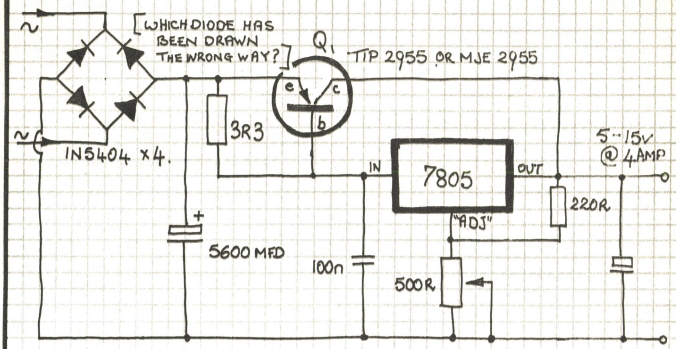
USE $4/7$ of $270R = 154\Omega$.

$$\frac{1}{154} = \frac{1}{R_B} + \frac{1}{270.}$$

$$154 = \frac{270R_B}{R_B + 270.}$$

$$\Rightarrow R_B = 358\Omega$$

USE 330Ω OR 390Ω.



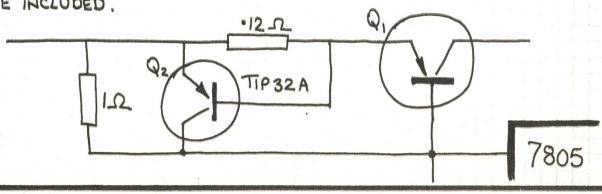
A VARIABLE 5-15v POWER SUPPLY.

THE BEST METHOD OF INCREASING THE OUTPUT VOLTAGE IS VIA A POT. THE 500R POT & 220R RESISTOR FORM A VOLTAGE DIVIDER NETWORK & THE OUTPUT CAN BE INFINITELY ADJUSTED BETWEEN 5 & 15 VOLTS WITHOUT THE OUTPUT RISING EXCESSIVELY AS IT IS VARIED, UP OR DOWN.

A POINTER CAN BE ADDED TO THE POT & A SET OF OUTPUT VOLTAGES MARKED ON A SCALE. YOU WILL NEED A MULTIMETER TO CHECK THE OUTPUT VOLTAGE WHEN CALIBRATING.

THE ABOVE CIRCUIT HAS ONE MAJOR DRAWBACK. IT DOES NOT HAVE ANY CURRENT LIMITING FEATURE. THE 7805 WILL NOT SHUT DOWN WHEN THE OUTPUT IS 4 AMPS AS MOST OF THE CURRENT IS FLOWING IN THE "TIP" TRANSISTOR.

ON SHORT-CIRCUIT THE MAXIMUM CURRENT WILL DEPEND ON THE CAPABILITIES OF THE POWER TRANSFORMER AND THIS COULD BE AS HIGH AS 6-10 AMPS. THIS EXCESS CURRENT COULD DAMAGE THE DIODES OR TRANSISTOR SO A CURRENT-LIMITING CIRCUIT SHOULD BE INCLUDED.



THE ADDITION OF Q_2 & A ·12Ω RESISTOR WILL LIMIT THE OUTPUT CURRENT TO 4-5 AMPS.
AS THE OUTPUT CURRENT RISES, THE VOLTAGE ACROSS THE ·12Ω RESISTOR TURNS Q_2 ON AND AT ABOUT 5AMPS THE VOLTAGE ACROSS THE ·12Ω IS ·6V ($V = IR$ $= 5 \times .12 = .6$)
THIS SATURATES Q_2 AND ROBS THE BASE OF Q_1 OF ANY FURTHER TURN-ON VOLTAGE. (WHEN Q_2 SATURATES - TURNS ON FULLY - THE VOLTAGE IT ALLOWS TO DEVELOP ACROSS ITS COLLECTOR AND EMITTER LEADS IS ONLY ABOUT ·3VOLTS. THIS IS TOO LOW TO TURN ON Q_1)

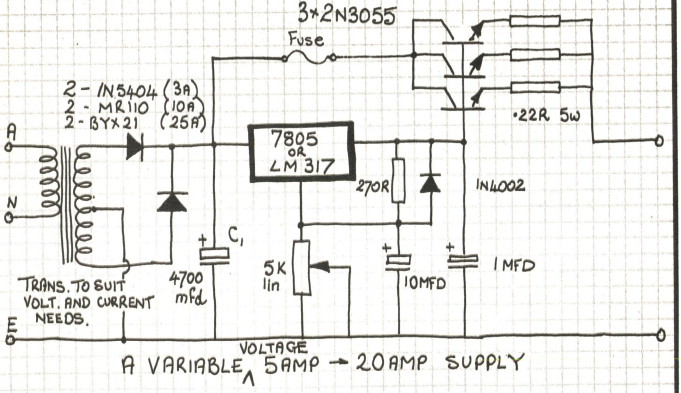
THUS THE SERIES-PASS TRANSISTOR WILL SETTLE AT A MAXIMUM CURRENT FLOW OF 4-5 AMPS.

USING 2N3055's

— J.W. Berglund. 3820.

A 2N3055 CAN BE USED AS AN EMITTER-FOLLOWER TO PRODUCE A HIGH CURRENT SUPPLY. THESE TRANSISTORS CAN BE PARALLELED UP TO SUPPLY 5-10-15 OR 20 AMPS

2N3055 TRANSISTORS ARE VERY CHEAP & READILY AVAILABLE.—THAT'S WHY THERE IDEAL FOR HEAVY CURRENT SUPPLIES.



THE ·22R RESISTORS ARE EQUAL LENGTHS OF "JUG SPIRAL" TO BALANCE THE CURRENT-SHARING IN THE 2N3055's. EACH 2N3055 WILL REQUIRE A HEAT SINK OF AREA 10CM × 10CM.
THE TRANSFORMER, POWER DIODES & FILTER ELECTROLYTIC (C_1) WILL HAVE TO BE CHOSEN TO SUIT THE VOLTAGE & CURRENT REQUIREMENTS.

THE USE OF A PRE-REGULATOR

IN SOME SITUATIONS A 7805 WILL NOT DELIVER THE NORMAL 1-AMP CURRENT. THIS MAY COME AS A SURPRISE!

AFTER ALL, A 7805 IS CAPABLE OF SUPPLYING 1·5 AMPS AND WILL LIMIT THE FLOW IF THE CURRENT TRIES TO EXCEED THIS VALUE.

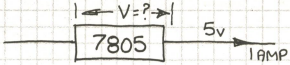
BUT IF THE VOLTAGE SUPPLIED TO THE REGULATOR IS TOO HIGH, THE POWER BEING LOST IN THE REGULATOR WILL CAUSE IT TO LIMIT THE CURRENT.

IN THIS SECTION WE WILL SEE HOW THIS OCCURS AND WHAT IS MEANT BY THE VOLTAGE BEING "TOO HIGH".

ONE OF THE MAIN FACTORS WHICH LIMITS THE CURRENT CAPABILITY OF A REGULATOR IS THE WATTAGE IT IS CAPABLE OF DISSIPATING.

FOR A 7805 OR ANY OF THE "PLASIC PACKAGE" REGULATORS IN THE TO 220 PACKAGE, THE MAX WATTAGE IT CAN DISSIPATE IS 20 WATTS.

IF WE TAKE THE CASE FOR A CURRENT FLOW OF 1-AMP, THE MAXIMUM VOLTAGE DROP ACROSS THE REGULATOR IS:



[CONSIDER THE REGULATOR TO BE A POWER RESISTOR FOR THESE CALCULATIONS]

$$\text{POWER} = \text{VOLTS} \times \text{AMPS}$$

$$20 = V \times 1$$

$$\Rightarrow V = \frac{20}{1}$$

$$= 20 \text{ VOLTS}.$$

THIS GIVES THE MAXIMUM INPUT VOLTAGE OF 20 + 5 [FOR A 7805]

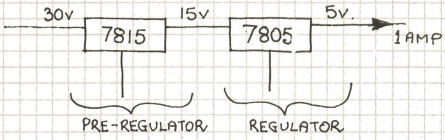
= 25 VOLTS.

IF THE INPUT VOLTAGE IS ABOVE 25 VOLTS, THE REGULATOR WILL BEGIN TO SHUT DOWN AT LESS THAN 1 AMP [THIS IS WELL BELOW THE SHUT-DOWN OF 1·5 AMP AND THIS WILL OCCUR SOLELY BECAUSE OF THE HEAT BUILD-UP].

BY USING A PRE-REGULATOR WE CAN USE THE 7805 ON A HIGHER INPUT VOLTAGE AND STILL ACHIEVE THE REQUIRED OUTPUT CURRENT.

THE SAME POWER LOSS WILL OCCUR BUT IT WILL BE DIVIDED BETWEEN 2 REGULATORS.

TAKE THE FOLLOWING EXAMPLE:



THE INPUT VOLTAGE FOR THIS EXAMPLE IS 30v.
THE OUTPUT OF THE 1ST REGULATOR IS 15v BECAUSE THE REGULATOR IS A 7815, AND THE 7805 SUPPLIES 5v.

THE LOSS IN THE PRE-REGULATOR WILL BE:

$$\text{POWER} = V \times I$$
$$= (30-15) \times 1$$
$$= 15 \text{ WATTS.}$$

THE LOSS IN THE 7805:

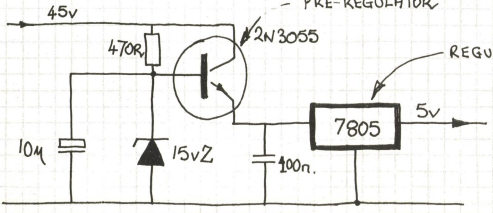
$$= (15-5) \times 1$$
$$= 10 \text{ WATTS.}$$

PROVIDED THE TWO REGULATORS ARE INSULATED FROM ONE ANOTHER AND ADEQUATELY HEAT SINKED THE COMBINED 15 + 10 WATTS CAN BE DISSIPATED WHILE SUPPLYING THE 1-AMP LOAD.

HOWEVER THERE IS A LIMIT TO THIS TYPE OF ARRANGEMENT.

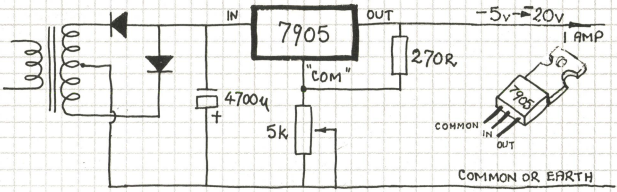
THE MAXIMUM INPUT VOLTAGE FOR THIS TYPE OF REGULATOR (IN THE 78xx SERIES) IS 35 - 40 VOLTS.

IF THE VOLTAGE IS ABOVE 45 VOLTS A TRANSISTOR PRE-REGULATOR WILL BE NEEDED. THE FOLLOWING CIRCUIT SHOWS HOW A 2N3055 CAN BE USED:



THE 7905

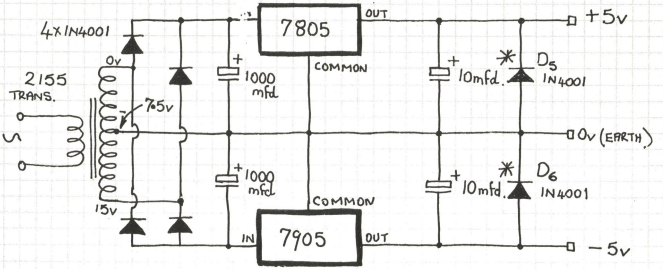
A NEGATIVE POWER SUPPLY USING A 7905 IS EXACTLY LIKE A POSITIVE SUPPLY EXCEPT THE POLARISED COMPONENTS ARE REVERSED.



A NEGATIVE SUPPLY.

THE POWER TRANSFORMER LEADS ARE NOT REVERSED AS IT IS NOT A POLARISED COMPONENT (IT DOES NOT HAVE FIXED, PERMANENT, POSITIVE END BUT ALTERNATES FROM ONE END (OR ONE LEAD) TO THE OTHER).

THE CIRCUIT FOR A NEGATIVE SUPPLY USUALLY ACCOMPANIES A POSITIVE SUPPLY & THUS IT IS DRAWN AS A MIRROR IMAGE OF THE POSITIVE SUPPLY.



A SIMPLE DUAL SUPPLY

* THE TWO DIODES IN THE OUTPUT (D_5 & D_6) WILL COME INTO OPERATION IF THE +5v IS CONNECTED TO THE -5v. DIODE D_5 SHORTS THE NEGATIVE VOLTAGE TO EARTH AND D_6 SHORTS THE POSITIVE VOLTAGE TO EARTH THIS PREVENTS A REVERSE VOLTAGE FROM ENTERING THE REGULATORS AND DAMAGING THEIR ZENER REFERENCE CIRCUIT.
OBVIOUSLY IT IS NOT WISE TO SHORT THE OUTPUT TERMINALS TOGETHER AS ALL DIODES ARE ONLY RATED AT 1 AMP.

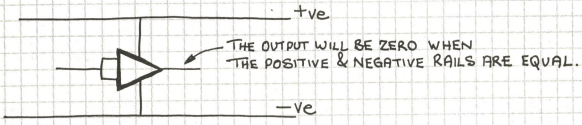
A DUAL TRACKING POWER SUPPLY

A POWER SUPPLY HAVING BOTH POSITIVE & NEGATIVE RAILS CAN BE DESIGNED TO HAVE EITHER A FIXED VOLTAGE OR AN ADJUSTABLE VOLTAGE.

IF THE VOLTAGE IS CAPABLE OF BEING ADJUSTED, IT IS ESSENTIAL THAT THE NEGATIVE VOLTAGE BE THE SAME AMPLITUDE AS THE POSITIVE.

THIS IS ESSENTIAL FOR OP-AMPS. 741'S OR 3140'S REQUIRE A SPLIT POWER SUPPLY IN WHICH THE POSITIVE & NEGATIVE RAILS ARE AS EQUAL AS POSSIBLE, TO EACH OTHER.

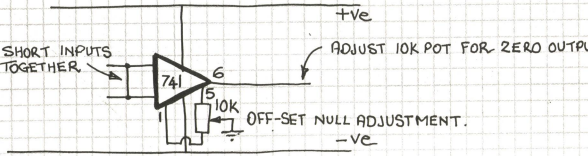
THIS IS NECESSARY AS WHEN THE TWO INPUTS OF AN OP-AMP ARE AT THE SAME POTENTIAL, THE OUTPUT WILL BE OFF-SET BY AN AMOUNT EQUAL TO THE DIFFERENCE IN RAIL VOLTAGES.



ANY OP-AMP WITH INPUTS SHORTED.

IF THE POSITIVE RAIL IS 10v & THE NEGATIVE RAIL −9.5v THE OUTPUT OF THE OP-AMP WILL BE +0.5v. THIS MAY NOT BE CRITICAL IN SOME CIRCUITS HOWEVER A BUFFER TRANSISTOR IN A COMMON EMITTER CONFIGURATION WILL BE TURNED ON AT THIS LEVEL.

AN OFF-SET NULL IS AVAILABLE ON SOME OP-AMPS TO COUNTER THE EFFECT OF UNEQUAL POWER RAILS.



USING THE OFF-SET NULL.

IDEALLY THE POSITIVE & NEGATIVE RAILS SHOULD BE EXACTLY THE SAME BUT IN PRACTICE A DIFFERENCE OF ABOUT 100mV TO 300mV IS TO BE EXPECTED. THE OFF-SET NULL PINS CAN BE CONNECTED TOGETHER VIA A POT TO OBTAIN A ZERO OUTPUT PROVIDED THE TWO INPUTS ARE SHORTED TOGETHER WHILE ADJUSTMENT IS MADE.

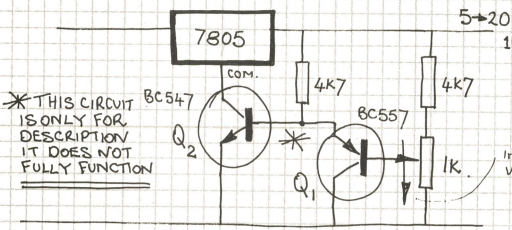
GENERALLY A TRACKING POWER SUPPLY IS DESIGNED SO THAT THE POSITIVE VOLTAGE IS ADJUSTABLE BY THE OPERATOR AND THIS VOLTAGE IS DETECTED BY A FEEDBACK ARRANGEMENT TO CONTROL THE NEGATIVE RAIL.

WHEN POWERING A CIRCUIT NEEDING DUAL VOLTAGES, YOU WILL FIND THAT MOST OF THE CURRENT IS DRAWN FROM THE POSITIVE RAIL AND ONLY A FEW HUNDRED MILLIAMPS IS DRAWN FROM THE NEGATIVE SUPPLY.

THIS MEANS A 1-AMP TRANSFORMER IN A DUAL SUPPLY WILL BE OPERATING WELL WITHIN ITS LIMITS. — AS THE NEGATIVE SECTION WILL BE DRAWING MINIMAL CURRENT.

THE SENSING ARRANGEMENT WHICH CONTROLS THE NEGATIVE VOLTAGE CAN BE A SET OF TRANSISTORS OR AN OP-AMP. BOTH ARRANGEMENTS WILL BE DISCUSSED, BEGINNING WITH A TRANSISTOR DESIGN.

FIRSTLY WE WILL LOOK AT HOW A SET OF TRANSISTORS CAN BE USED TO ADJUST THE VOLTAGE OF A 3-TERMINAL REGULATOR.



INCREASING THE OUTPUT VOLTAGE WITH TRANSISTORS.

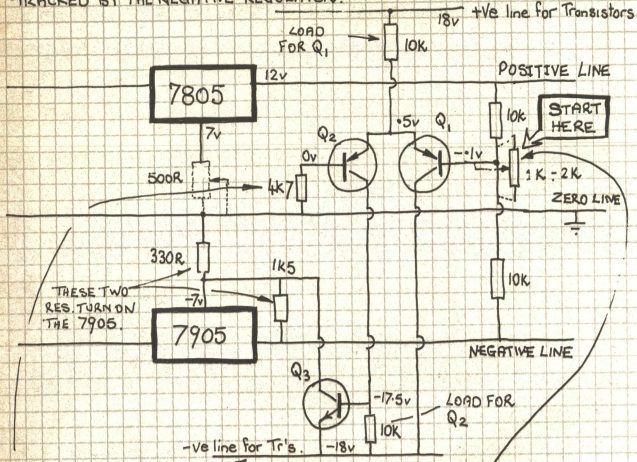
THE CIRCUIT SHOWS HOW THE OUTPUT VOLTAGE OF A 7805 CAN BE INCREASED BY USING A 2 TRANSISTOR AMPLIFIER. THIS IS ONLY A DEMONSTRATION CIRCUIT TO DESCRIBE THE OPERATION OF THE COMPONENTS. — IT DOES NOT FULLY FUNCTION.

TRANSISTOR Q_1 IS AN EMITTER-FOLLOWER & THE EMITTER IS ALWAYS ·6v HIGHER THAN THE BASE.

AS THE 1K POT IS ROTATED IN THE DIRECTION SHOWN THE BASE VOLTAGE DECREASES & THE EMITTER FOLLOWS, EXACTLY. THIS EMITTER VOLTAGE IS PASSED TO TRANSISTOR Q_2 WHICH IS CONNECTED AS A COMMON EMITTER AMPLIFIER & AS THE BASE VOLTAGE DECREASES, IT IS TURNED OFF SLIGHTLY. THE EFFECTIVE RESISTANCE BETWEEN COLLECTOR & EMITTER INCREASES & THUS THE VOLTAGE ON THE "COM" TERMINAL INCREASES TO GIVE A HIGHER OUTPUT VOLTAGE.

TRACKING USING TRANSISTORS

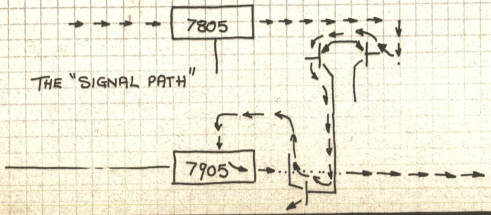
THE CIRCUIT WE WILL BE ANALYZING CONSISTS OF 3 TRANSISTORS TO PROVIDE THE TRACKING FEATURE. THE POSITIVE REGULATOR IS TRACKED BY THE NEGATIVE REGULATOR.



THE 4K7 IS ONLY A "SAFETY RESISTOR" NO CURRENT FLOWS IN THE BASE CIRCUIT & THE BASE CAN BE CONSIDERED TO BE A ZERO POTENTIAL.

THIS VOLTAGE IS NOT CRITICAL. IT COULD BE -9v TO -30v. AND THE CIRCUIT WILL STILL OPERATE.

THE JOIN OF THE TWO 10K RESISTORS WILL BE AT ZERO VOLTAGE DUE TO THE POSITIVE LINE BEING EQUAL IN AMPLITUDE TO THE NEGATIVE LINE. [WE MEASURED IT TO BE -·1v].



THE TRACKING FEATURE

THE OPERATION OF THE 3-TRANSISTOR TRACKING CIRCUIT LIES IN THE BIASING OF Q_1. YOU CAN SEE THAT THE VOLTAGE BETWEEN BASE & EMITTER OF Q_1 IS $-\cdot1v + \cdot5v = \cdot6v$, & THIS MEANS THAT Q_1 IS TURNED ON. — NOT HARD ON — JUST BEGINNING TO BE TURNED ON.

Q_1 IS AN EMITTER FOLLOWER & THIS MEANS THE EMITTER IS ALWAYS ·6V HIGHER THAN THE BASE. FOR EXAMPLE: IF THE BASE COULD BE SET AT 3V, THE EMITTER WOULD BE 3·6V. IF BASE WAS −4V THE EMITTER WOULD BE −3·4V. THE DIFFERENCE BETWEEN BASE & EMITTER WILL ALTER ONLY VERY SLIGHTLY AND WE HAVE NEGLECTED IT AT THE MOMENT.

OUR FIRST FACT TO REMEMBER IS: Q_1 IS NOT A VOLTAGE AMPLIFIER. IT IS A CURRENT AMPLIFIER. ONLY A VERY SMALL CURRENT FLOWS IN THE BASE CIRCUIT AND Q_1 IS ABLE TO ADJUST THE EMITTER VOLTAGE OF Q_2 WHICH TAKES CONSIDERABLY MORE "EFFORT" OR CURRENT TO MOVE ITS EMITTER HIGHER OR LOWER.

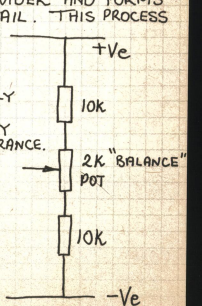
WHEN THE EMITTER OF Q_2 IS INCREASED OR DECREASED, (BY ONLY THE FEW MILLIVOLTS OBTAINED FROM THE 1K BALANCE POT) THE COLLECTOR VOLTAGE INCREASES OR DECREASES BY A VALUE 50-70 TIMES HIGHER IN AMPLITUDE AS THIS IS THE GAIN OF THE TRANSISTOR.

THIS VOLTAGE CHANGE IS PASSED TO THE BASE OF Q_3 WHICH FURTHER AMPLIFIES THE VOLTAGE SO THAT THE EFFECTIVE RESISTANCE BETWEEN THE COLLECTOR AND EMITTER LEADS IS REDUCED. A VOLTAGE DIVIDER IS MADE UP BETWEEN THE 330R RESISTOR AND THE TRANSISTOR SO THAT THE VOLTAGE APPEARING ON THE COMMON TERMINAL OF THE 7905 IS INCREASED.

THE 7905 SENSES (DETECTS) THIS VOLTAGE AND INCREASES THE NEGATIVE OUTPUT VOLTAGE ACCORDINGLY. THIS INCREASE IS PASSED TO THE BASE OF Q_1 VIA THE 10K:10K VOLTAGE DIVIDER AND FORMS A FEEDBACK LOOP TO STABILIZE THE NEGATIVE RAIL. THIS PROCESS IS CALLED TRACKING.

WHY THE BALANCE POT IS SO "CRITICAL"

ADJUSTING THE BALANCE POT (1K OR 2K TRIM) BY ONLY A FEW HUNDRED OHMS WILL SHIFT THE NEGATIVE VOLTAGE 1 OR 2 VOLTS. THIS MID POINT IS EXTREMELY CRITICAL AND THE 10K RESISTORS SHOULD BE 1% TOLERANCE. BY USING A MINITRIM POT, 5% RESISTORS CAN BE USED.
THE REASON WHY THE MID POINT IS SO SENSITIVE TO VOLTAGE FLUCTUATIONS LIES IN THE AMPLIFYING EFFECT OF TRANSISTORS Q_2 & Q_3. A CHANGE IN THE BASE VOLTAGE OF Q_1 BY 1 MILLIVOLT WILL ALTER THE OUTPUT OF THE 7905 BY 1 VOLT.
THE COMBINED GAIN OF Q_2 & Q_3 WILL BE ABOUT 1000.



HOW THE SUPPLY "TRACKS"

WHEN THE POSITIVE VOLTAGE IS INCREASED BY THE OPERATOR TURNING THE 500R "VOLTAGE POT", THE VOLTAGE AT THE MID POINT OF THE TWO 10K RESISTORS WILL MOVE IN THE POSITIVE DIRECTION. THIS WILL INCREASE THE VOLTAGE ON THE BASE OF Q_1 & SINCE IT IS AN EMITTER FOLLOWER, THE EMITTER WILL INCREASE BY AN EQUAL AMOUNT.

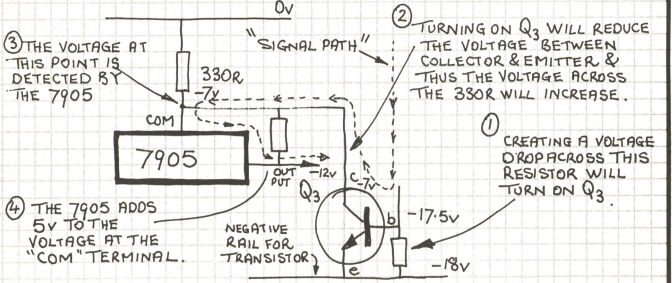
THIS INCREASE WILL BE PASSED TO Q_2 (VIA THE DIRECT EMITTER COUPLING) AND THE EMITTER OF Q_2 WILL BE FORCED TO RISE SLIGHTLY.

THE BASE OF Q_2 DRAWS VERY LITTLE CURRENT THROUGH THE 4K7 RESISTOR AND IT CAN BE CONSIDERED TO BE AT ZERO POTENTIAL.

THE VOLTAGE BETWEEN BASE AND EMITTER OF Q_2 WILL INCREASE BY AN AMOUNT EQUAL TO THE MILLIVOLTS PICKED OFF THE VOLTAGE DIVIDER NETWORK AND WILL BE TURNED ON SLIGHTLY HARDER. THIS WILL INCREASE THE CURRENT THROUGH THE LOWER 10K RESISTOR AND THUS THE VOLTAGE DROP ACROSS THIS RESISTOR WILL TURN ON Q_3.

TRANSISTOR Q_3 IS A COMMON EMITTER WITH THE 330R AS ITS LOAD RESISTOR. AS Q_3 TURNS ON HARDER, THE VOLTAGE DROP ACROSS THE 330R INCREASES.

THE 7905 SENSES THIS VOLTAGE ON ITS COMMON TERMINAL AND PRODUCES AN OUTPUT WHICH IS 5 VOLTS HIGHER. THE OUTPUT OF THE NEGATIVE RAIL IS FED BACK TO THE VOLTAGE DIVIDER NETWORK AND TENDS TO TURN OFF Q_1 SO THAT AN EQUILIBRIUM IS SET UP IN THE TRANSISTOR NETWORK AND BOTH OUTPUT LINES ACHIEVE THE SAME AMPLITUDE.


0v
"SIGNAL PATH"
2 TURNING ON Q3 WILL REDUCE THE VOLTAGE BETWEEN COLLECTOR & EMITTER & THUS THE VOLTAGE ACROSS THE 330R WILL INCREASE.
3 THE VOLTAGE AT THIS POINT IS DETECTED BY THE 7905
330R
-7v
COM
7905
OUT PUT
-12v
Q3
-7v
1 CREATING A VOLTAGE DROP ACROSS THIS RESISTOR WILL TURN ON Q3.
4 THE 7905 ADDS 5v TO THE VOLTAGE AT THE "COM" TERMINAL.
NEGATIVE RAIL FOR TRANSISTOR
b
-17·5v
e
-18v

HOW Q_3 INCREASES THE -VE RAIL VOLTAGE.

QUIZ

Find out how much you have learnt. Answer these questions without referring to the notes. Then use the index on P 28 to look up the answers.

1. What is the difference between conventional current and electron flow?

2. The primary function of a power supply is to convert _____ to _____.

3. A power supply is isolated from the mains via a _____

4. The two windings of a simple transformer are called _____ and _____.

5. A single-ended transformer has _____

6. A transformer output is measured in VA. What is VA?

7. A 6v winding and a 12v winding on a transformer can be paralleled together T/F?

8. A 12v winding will have a higher resistance than a 6v winding. T/F?

9. What does RMS mean?

10. What wattage will be dissipated by a diode when passing 1 amp?

11. What is bleed current?

12. What will be the result if two transformers are connected out-of-phase?

13. Name three types of filters. Which is best?

14. How does a resistor and zener diode produce voltage regulation?

15. What does a pre-regulator do?

16. Draw a series-pass regulator circuit.

17. Draw the outline of a 7805 and label the three leads.

18. Can a 7805 take the place of a 7905?

19. Draw a bridge rectifier and show the 4 diodes clearly.

20. What will happen if the common terminal of a 7805 is left open?

21. Why is it so dangerous to short the positive output to the negative output of a dual voltage power supply?

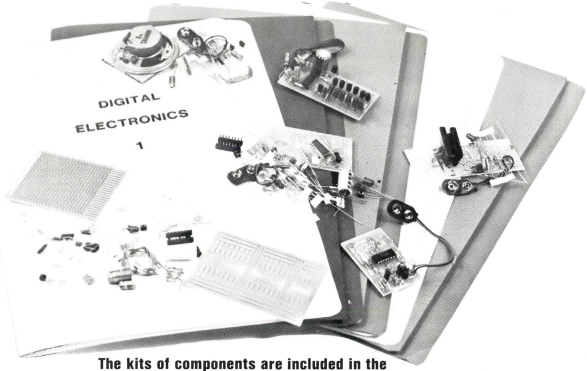
22. How can a fixed voltage regulator such as a 7805 produce higher output voltages?

23. What does TRACKING mean?

24. What is means by a regulator dropping out of regulation?

Learn DIGITAL ELECTRONICS with:

THE AUSTRALIAN DIGITAL ELECTRONICS SCHOOL



The kits of components are included in the course. (The 2 finished projects are student models). The probe on the reverse side of the page is also included in the course.

Todays rapidly expanding technology almost entirely revolves around digital electronics. Now is the time to learn and master this enormously valuable technology. With a secure grasp of digital operations, you can be assured of a safe and rewarding career. But you must know basic electronics absolutely. THE AUSTRALIAN DIGITAL ELECTRONICS SCHOOL covers these requirements with a new digital course. And the price is an exceptionally low $100. The basic theme of the course is to get you acquainted with digital building blocks through programmed instruction, combined with actual construction.

The course consists of 5 lessons. You will be required to construct 2 digital projects and you will start with a preliminary parts identification and soldering ability test. From there you will be guided through 2 interesting projects which are sent into the school for examination and marking. These will be returned and **remain** your property.

A test accompanies each lesson and these are also sent into the school to be corrected by your instructor.

Individual attention will be given to each student and you progress at your own rate. This is the most important aspect of this course. You can repeat any section until it is fully understood. You can also ask for any additional help relevant to the topic.

So don't delay. This may be the turning point in your career. You may think you know electronics, but until it is put to the test and you receive an assessment, you may have some false understandings.

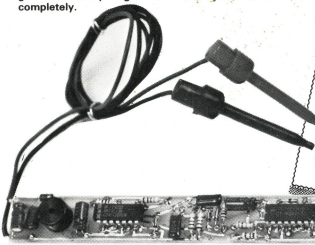
The reverse side of this page contains your PRELIMINARY TEST. Answer the questions without seeking any additional help as this will be used as your beginning reference level.

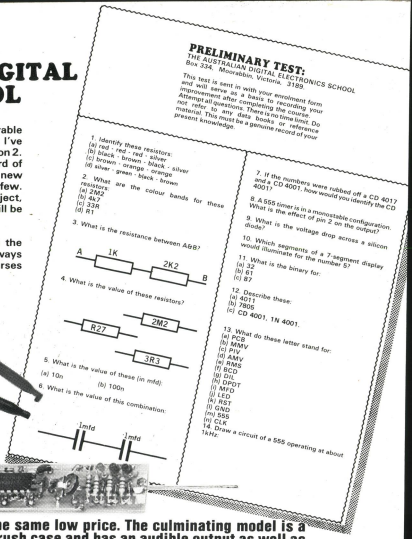
THE AUSTRALIAN DIGITAL ELECTRONICS SCHOOL, Box 334 Moorabbin, Victoria, 3192

THE AUSTRALIAN DIGITAL ELECTRONICS SCHOOL

We have received a lot of letters and favourable comments about the course already. . . things like: I've learnt so much from the first lesson, please send lesson 2. Another student wrote: "it's up to the high standard of TALKING ELECTRONICS" and "it's given me a new understanding of Digital Electronics." . . just to list a few. If you enjoyed the Dual Tracking Power Supply project, but feel you would like to know more, this course will be what you are looking for.

It's so good it's guaranteed. If you don't find the the course is for you, it can be returned for refund. We always guarantee everything because we back our courses completely.





PRELIMINARY TEST:
THE AUSTRALIAN DIGITAL ELECTRONICS SCHOOL
Box 334, Moorabbin, Victoria 3189.

This test is sent in with your enrolment form and will serve as a basis for recording your improvement after completing the course.
Attempt all questions. There is no time limit. Do not refer to answers. The test is for your personal information only.
Please be a genuine record of your present knowledge.

1. Identify these resistors:
(a) red - red - silver
(b) black - brown - black - silver
(c) brown - orange - orange
(d) silver - green - black - brown

2. What are the colour bands for these resistors:
(a) 2M2
(b) 4k7
(c) 33R
(d) R1

3. What is the resistance between A&B?

4. What is the value of these resistors?

5. What is the value of these (in mfd):
(a) 10n (b) 100n

6. What is the value of this combination:

7. If the numbers were rubbed off a CD 4017 and a CD 4001, how would you identify the CD 4001?

8. A 555 timer is in a monostable configuration. What is the effect of pin 2 on the output?

9. What is the voltage drop across a silicon diode?

10. Which segments of a 7-segment display would illuminate for the number 5?

11. What is the binary for:
(a) 32
(b) 61
(c) 87

12. Describe these:
(a) 4011
(b) 7805
(c) CD 4001, 1N 4001

13. What do these letter stand for:
(a) PCB
(b) MMV
(c) RYV
(d) AMV
(e) RMS
(f) BCD
(g) DCD
(h) DPDT
(i) MFD
(j) LED
(k) REF
(l) GND
(m) SSS
(n) CLK
14. Draw a circuit of a 555 operating at about 1kHz.

The course now includes 3 models for the same low price. The culminating model is a DIGITAL LOGIC PROBE. It fits into a toothbrush case and has an audible output as well as HIGH - LOW and PULSE via three 3mm coloured LEDs.

ENROLMENT FORM:
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Photocopy this page or apply on a plain sheet of paper. You will be sent a PRELIMINARY TEST sheet by return mail.

Name: .....

Address:.....post code:.....

I wish to enrol for the DIGITAL ELECTRONICS course:
( ) I enclose $100 as full payment.
( ) I enclose $20 for the first lesson.
( ) I enclose $..... for .....lessons.
( ) Please send lesson 1 COD. I will pay the postman $24.
You can order 1, 2, 3, 4 or 5 lessons or you can pay for 1 lesson at a time.

Please debit my bankcard: $.....

4 9 6 ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

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OFFICE USE:
Lesson:
1 %
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3 %
4 %
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